Engin.
Library

MAY 21 1930

INSTRUMENTS

NDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Devoted to Measurement and Control Problems

Vol. 3. No. 5 Pittsburgh, Pa. May, 1930

IN THIS ISSUE

The Practical Difficulties of Introducing the Metric System into the United States
WILLIAM E. BULLOCK

◆

Measurement of Air Flow E. OWER

◆

Measurements—Industrial and Scientific
DR. WALTER BLOCK

◆

The Engineer's Handbook of Industrial Instruments M. F. BÉHAR

◆

New Instruments

A Flow Ratio Recorder-Controller
The Photo-Electric Relay
Knock Testing Apparatus
Acceleration & Deceleration Recorder

Place initials of interested persons in your organization opposite title and call it to their attention.

AMPS
FUSE
VOLTS
AMPERES & VOLTS D.C.
D.C. VOLT-AMMETER

Model 540

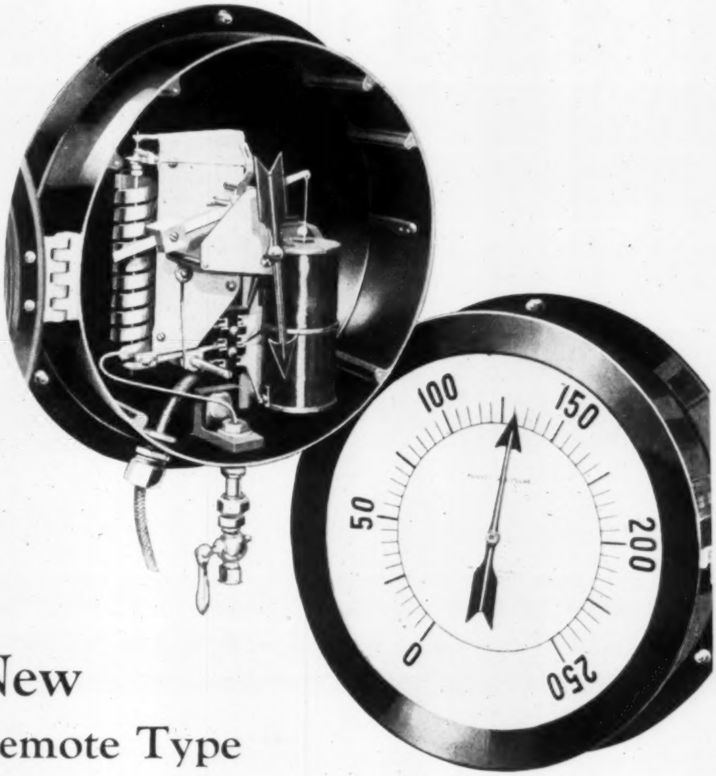
Precision Triple Range

D. C. Volt-Ammeter

A NEW instrument by Weston which makes its bow this season. No introductions are necessary to those familiar with its prototype, the Model 280, except to call attention to the rugged serviceability of this meter and its unique features of construction. When closed, the sensitive movement is completely protected in its handsome case of black bakelite—small and compact for pocket-portable use. When opened, the convenient features of this design for speed and accuracy of testing are at once apparent. By means of an ingenious Range Selecting Switch voltmeter and ammeter readings are obtainable almost simultaneously. The instrument is provided with mirror scale and knife-edge pointer. Voltmeter sensitivity, 100 ohms per volt. Accuracy, 1%.

WESTON ELECTRICAL INSTRUMENT CORP.
591 Frelinghuysen Ave., Newark, N. J.

Weston
PIONEERS SINCE 1888
INSTRUMENTS



New

Remote Type

Pressure Gauges . . .

The new Brown Remote Type Pressure Gauges with the special Helix unit operating in conjunction with an inductance coil give accurate data—without trouble from varying line voltage—at distances up to 30 miles from the transmitter.

Write for Catalog No. 7501

THE BROWN INSTRUMENT COMPANY
4482 WAYNE AVE., PHILADELPHIA, PA.
Branches in 20 principal cities

Brown Instruments

"to measure is to economize"

When writing to the above company, please mention INSTRUMENTS

A NEW *Improved* MULTIMETER

FOR DIRECT CURRENT
14 RANGES

MULTIMETER
RAWSON ELECTRICAL INSTRUMENT CO.
CAMBRIDGE, MASS.
FULL SCALE
100
1000
10
2
1
.02
.01
.002
+ COMMON
CURRENT
ZERO
CLAMP
VOLTS

1 microampere to 1 ampere (1,000,000 mics)
20 microvolts to 1000 volts

Just 3 Binding Posts and 1 Selector Switch

Specially suitable for covering both minimum and maximum readings on
separate mounted thermo couples in vacuo
For High Frequency Work

RAWSON
ELECTRICAL INSTRUMENT CO.

INCORPORATED 1918
CAMBRIDGE, MASS.
Branch Offices: 91 Seventh Avenue, New York City

Also Manufacturers of AC or DC Thermal Multimeters, Microammeters, Milliammeters and Ammeters, Microvoltmeters, Millivoltmeters, and Voltmeters, Cable Testers, Timers, Earth Current-Meters, Fluxmeters, Thermo Junctions, Electrostatic Voltmeters, Wattmeters, etc.

Write for bulletins.

Mercury Column Temperature Control No Longer Necessary!

Precision Barometer
Patented
29
30
28
31
27
System Paulin
Stockholm
MADE IN SWEDEN BY C. E. JOHANSSON, ESKILSTUNA

The **Paulin** Laboratory Barometer is temperature-corrected—more accurately and quickly read—more sensitive to slight changes in pressure.

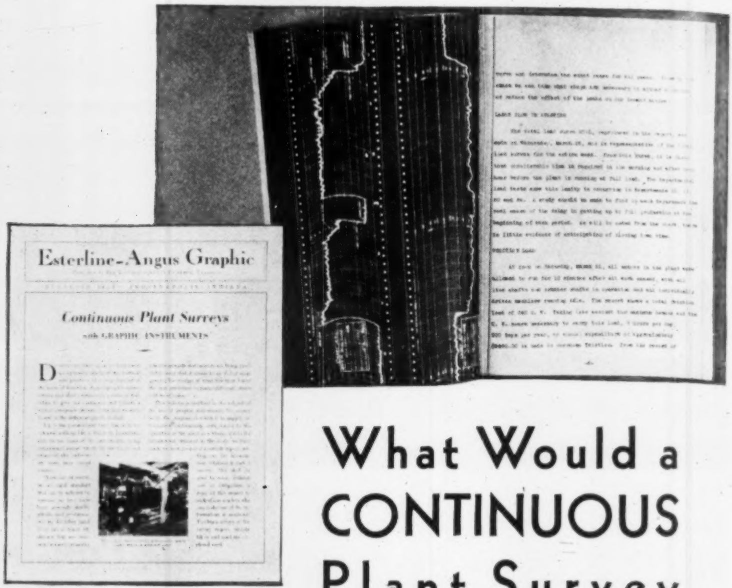
You can read the *Paulin instantly!*

"We find the Paulin much more convenient"—"It saves time"—"We are confident of accuracy when the Paulin is used—while errors may occur when correcting mercury readings for temperature" . . . These are extracts from letters enthusiastically endorsing the Paulin Barometer—written by the leading scientific laboratories of the world! Yet many scientists still do not realize that the discovery of the Paulin principle has revolutionized the measurement of air pressure—making possible a sensitivity and accuracy never before believed possible!

FREE—**BOOK ON AIR PRESSURE.** For booklet explaining these sensational new instruments and their many uses, sign below and mail to The American Paulin System, Inc., Dept. I-5, 1220 Maple Ave., Los Angeles, Calif.

Name ....

Address .... City ....



Esterline-Angus Graphic

Continuous Plant Surveys

with GRAPHIC INSTRUMENTS

What Would a CONTINUOUS Plant Survey of Conditions in Your Plant Reveal?

This Bulletin and Report Will Tell You

WHAT is a plant survey? What information of value does it reveal? How may it be made in *your plant?*

On account of the increasing demand for accurate knowledge of the three elements which enter into the *cost* of any manufactured commodity or service—*Labor, Power, and Maintenance*—Esterline-Angus Engineers have prepared a special bulletin and specimen report dealing with every phase of this important subject.

How Power loads affect demand and current charges, and how to adjust them; finding unnecessary "lapses" in productive labor; locating excessive friction and faults in equipment; improving power factor and voltage conditions; "spotting" overloaded and underloaded motors, etc., etc. All of these points of investigation, with suggestions for improvement, are covered thoroughly in this bulletin and report.

The advantages of Esterline-Angus Recording Meters for such tests and surveys are too many for listing here. Their accuracy, convenient portability, and dependability are well known—but the fact that these instruments furnish continuous records over any period of time up to a full week, *without attention,* is a very important consideration. The bulletin and report are FREE. May we send them?

THE ESTERLINE-ANGUS COMPANY

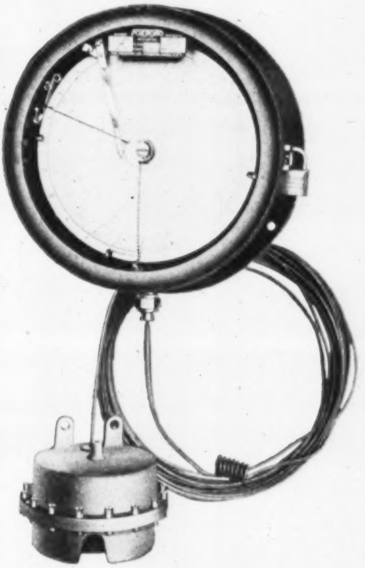
INDIANAPOLIS, U. S. A.

Pioneers in the Manufacture of Graphic Recording Instruments

When writing to the above company, please mention INSTRUMENTS

FOXBORO

Instruments *for* Liquid Level Measurement



PULP and Paper Mills, Textile Mills, Steel Mills, Rubber Works, Sugar Refineries, Oil Refineries, Chemical Plants, Cement Industries, Waterworks, Sewage Systems, Power Plants, Hydro-Electric Plants, Hospitals, Cold Storage Warehouses—*all these and other industries look to Foxboro* for instruments to record and control liquid levels in tanks, reservoirs, rivers, filters, weirs, sewage systems and a hundred other places.

These Foxboro Instruments are known everywhere for accuracy and dependability.

- Recording Liquid Level Gauges
- Indicating Liquid Level Gauges
- Boiler Water Level Gauges
- Liquid Level Controllers
- Liquid Flow Meters
- Liquid Flow Controllers

Write to Dept. A. E. for complete information.

THE FOXBORO COMPANY
NEPONSET AVENUE, FOXBORO, MASS., U. S. A.

New York
Detroit
San Francisco
Salt Lake City
Chicago
Cleveland
Boston
Philadelphia

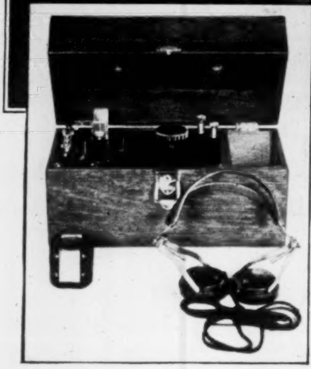
FOXBORO
REG. U. S. PAT. OFF.
THE COMPASS OF INDUSTRY

Pittsburgh
Rochester, N. Y.
Portland, Ore.
Tulsa
Los Angeles
Dallas
Atlanta

Instruments for Controlling, Recording and Indicating Temperature, Flow, Humidity and Pressure.

When writing to the above company, please mention INSTRUMENTS

L & N SOILS BRIDGE
FOR DETERMINING SOIL ALKALINITY



1. Primarily Intended for Measuring Conductivity of Soils and Soil Solutions in the Field.
2. Entirely Self-Contained.
3. Battery and Buzzer Easily Accessible.
4. Compact—Shown at Left 1/6 Actual Size.
5. Light—Weighs 9 pounds 2 ounces.
6. Strong—Built for Hard Knocks in the Field.
7. Originally designed by Bureau of Soils; see Dept. of Agriculture Circular 423. The bridge has been simplified by this company.

THE Portable Soils Bridge is used by railroads, oil companies and others interested in large-scale investigations of soil alkalinity.

This instrument is essentially an a. c. Wheatstone bridge. The measuring circuit carries an alternating current, secured from a self-contained dry cell by means of a buzzer and induction coils. The balance detector is a telephone. The cup for holding the sample is detachable. In every detail the Bridge is planned for rapid work, well within the limits of accuracy required of field studies.

No. 4966 BUREAU OF SOILS CONDUCTIVITY BRIDGE $155.00

LEEDS & NORTHRUP COMPANY
4901 STENTON AVENUE PHILADELPHIA, PA
LEEDS & NORTHRUP

ELECTRICAL MEASURING INSTRUMENTS POTENTIOMETER PYROMETERS
HUMP AND HOMO HEAT TREATING FURNACES AUTOMATIC COMBUSTION CONTROL

G-193

When writing to the above company, please mention INSTRUMENTS

TABLE OF CONTENTS

VOLUME 3 MAY, 1930 NUMBER 5

PAGE

Editorial 277

The Practical Difficulties of Introducing the Metric System into the United States—
WILLIAM E. BULLOCK 279

Measurement of Air Flow—E. OWER 283

Measurements—Industrial and Scientific—
DR. WALTER BLOCK 295

The Engineer's Handbook of Industrial Instruments—
M. F. BÉHAR 317

New Instruments:

A Flow Ratio Recorder-Controller 337
The Photo-Electric Relay 339
Knock Testing Apparatus 341
Acceleration & Deceleration Recorder 344

Catalogue Library 11
INSTRUMENTS' Book-of-the month 278
INSTRUMENTS' Book Shelf 282
Current Literature Review 14
Guyers' Guide 18
Advertisers' Index 25
Index Card Section 26

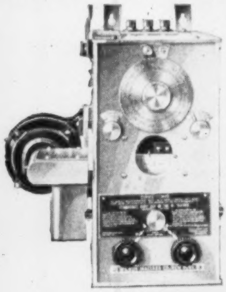
Published the 15th of each month by
INSTRUMENTS PUBLISHING COMPANY
1117 WOLFENDALE STREET, PITTSBURGH, PA.
JOSEPH J. VIGNEAU, *President* RICHARD RIMBACH, *Vice-Pres. & Treasurer*

TERMS OF SUBSCRIPTION
Anywhere in the world, $2.00 a year
Current Copies, 25 cents each

Address all inquiries and correspondence to Pittsburgh Office
Telephone FAirfax 6477

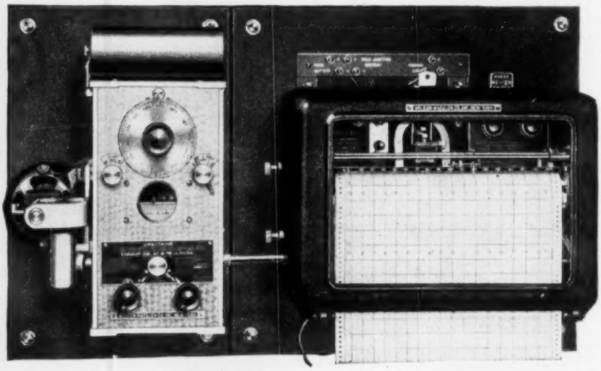
NEW ENGLAND: James H. Condon, 86 St. Botolph Street, Boston, Massachusetts
WESTERN NEW YORK STATE: Paul F. Herrick, 823 Powers Bldg., Rochester, N. Y.

Copyright, 1930, by Instruments Publishing Company



One high grade and husky motor for several temperature control or record units is the modern way.

Hundreds of our pyrometer controllers are operating in groups wherein six or eight control units are driven by a single motor.



A powerful motor driving a train of precision apparatus.

WILSON-MAEULEN Co
INCORPORATED
387 Concord Ave. New York, N. Y.

INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Vol. 3, No. 5 MAY, 1930 Pittsburgh, Pa.

To Our Readers

EFFORTS have been made from time to time to create sentiment in favor of legislation to make the adoption of the metric system of weights and measures compulsory in the United States. The metric system is already legal in this country and has been since 1866.

A single system of weights and measures for use the world over is very desirable—this is also true for a single language.

The editor does not like the compulsory feature of the proposed legislation, and further believes that careful thought should be devoted to this question before such legislation is passed, especially when we consider the experience gained to-date in enforcing the Volstead act.

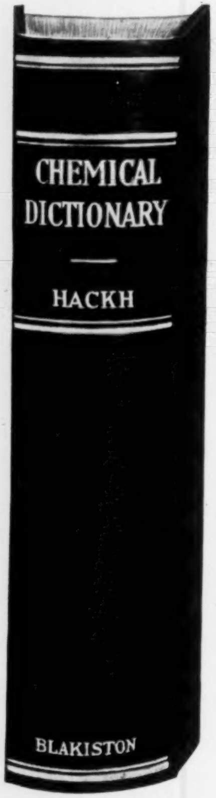
About ninety percent of the people in the United States care little what system is used. It is this decided lack of interest which makes it possible for us to have passed laws, which do not meet the approval of the majority. The engineers and all others concerned with measurement, should be actively interested in this question though, as in all probability the action taken by our legislators will depend upon the "amount of noise" made by either group on this question.

The editor also believes it more advisable to determine the sentiment in regard to the Tilson Bill before such a bill is passed rather than subsequently balloting to determine the sentiment as is the case with the *Literary Digest* poll.

In this issue appears an article by a representative of the *American Institute of Weights and Measures*. Next month will appear an article by a representative of the *Metric Association*. Beginning in July, INSTRUMENTS will make an effort to determine the opinions of those, who should be interested in this matter.

In 1932 the decennial check of the *British Standards of Weights and Measures* will be made. The editor believes that it is very important to see that there be no difference between the standards of the two great English speaking nations, and also that an International Agreement on the values of the primary inch standards be secured. At present this is more important than to make the metric system compulsory. It is therefore recommended that the United States construct new yard bars to be checked at that time.

INSTRUMENTS
Book - of - the - Month



Over 33,000 Terms Defined

Chemical Dictionary

by

INGO W. D. HACKH

Prof. of Chemistry, College of Physicians & Surgeons

Progress of Chemistry has been very rapid and expansive. Hackh contains over 33,000 words, covering all branches of chemistry.

The Purpose has been to provide a scientific, modern, precise and intelligible dictionary of chemistry of today, such as has not heretofore existed. The book is very inclusive, thorough in detail, illustrated, and contains many original diagrams helpful in practical chemistry and of great pedagogical value.

Pronunciation is given in simple English phonetics intelligible to all at a glance.

Synopsis of Contents. States precisely the theories, laws, rules; describes elements, compounds, drugs, minerals, vegetable and animal products; lists reactions, processes, methods; mentions apparatus and equipment. There are over 100 tables of various pertinent data, mostly original and scientifically accurate.

Bound in Handsome and Durable Fabrikoid. Approximate Size, 7 x 10 x 2. Price, $10.00, Postpaid.

Send your order to
INSTRUMENTS BOOK SHELF
INSTRUMENTS PUBLISHING COMPANY
1117 Wolfendale St., Pittsburgh, Pa.

BUY - A - BOOK - A - MONTH - FOR
YOUR - MEASUREMENT - LIBRARY

The Practical Difficulties of Introducing the Metric System into the United States

*William E. Bullock**

SO strong is the sentiment in some quarters for the "compulsory introduction of the International Metric System of Weights and Measures into the United States," that it is very difficult today to find an impartial evaluation of the difficulties with which we are confronted as soon as we abrogate our customary units of weight and measure.

Perhaps the greatest obstacle of all is the lethargy and unconcern of millions of our people, who care no more about the International Metric System than they do about the Japanese religion, the Soviet five-day calendar, or the income tax in Esthonia. Suppose Congress did decree the change in our fundamental standards of weight and measure, the effect might easily be unnoticeable; for the decree would mean nothing at all to millions.

To take a simple, but forceful, example, suppose Congress decreed the replacement of the yard, foot, and inch by the meter, decimeter and centimeter—which would bring this country into the Metric group—and suppose a man is in the business of buying and selling apples, as many men are. Then this man, instead of selling apples by the barrel, by law 26 inches high, 64 inches maximum circumference, and 7056 cubic inches capacity, would be selling apples by the barrel 6.5 decimeters high, 16 decimeters maximum diameter, and 11.56 cubic decimeters capacity.

Before the change he is selling barrels of apples; after the change he is selling barrels of apples. The barrel before the change looks the same, costs the same, sells for the same, as the barrel after the change. The only difference is that after the change, to manufacture the barrel the workman uses a different rule—if he uses a rule at all, and not just a wooden gage. After the change, the dimensions of the standard barrel are given in state laws and in the Federal law in metric units. But to the man who buys and sells apples, a barrel is a barrel, and *there has been no change*.

Therefore why not have the Metric System? Why not? Simply because ten years after we made the change, the apple dealer would still be writing to the barrel manufacturer "I got a new Ford truck, and I could load 12 barrels on to it,—four rows with three barrels each—were it not for the fact that the darned barrels are just two inches too large in diameter, and I just can't squeeze them in and close the tailboard. Why aren't these barrels made a couple of inches higher . . ." And this is the principal story.

Apples, bread, bricks, butter, charcoal, clams, coal, corn, peas, fish, flour, fruit and vegetables, gasoline—yes, let's stop there for a minute and consider the practical difficulty of introducing the metric system as far as the sale of gasoline is concerned. Gasoline hits everybody today.

---

*Member American Society of Mechanical Engineers; Fellow American Advancement of Science; Secretary American Institute of Weights and Measures

Statistics and figures there are plenty, but we only need the simplest. We only need to recall that there are 25,000,000 cars running around this country today, and that they all use gasoline, bought by the gallon—sometimes only a gallon at a time, and sometimes ten, five, six, or seven, or what not. If Congress put in the metric system, these gallons would become liters. Alright, that is easy. The pumps will all be recalibrated. The manufacturers of cars will change the dial readings, and all that. But for years mother will still persist: "We do need a new car. The car has become so shabby, and I am sure it is uneconomical. I am sure it is not doing more than 9 or 10, and it should be doing 15." Even mothers know these figures in the days of family budgets. And we shall not really get the metric system till mother gets the new figures.

Gasoline, grapes, hay, ice, lime, meat, milk, oils, paint, pig iron, . . . and so on all through the alphabet. The mention of each name conjures up associations and trade customs, in which usually some one unit of weight or measure is involved, and in which the name and value of this unit is so ingrained in the minds of millions of people that they can now never change.

They can now never change, although revolutionary changes have been, and are still being made in different places in the world today. But investigation invariably shows that these changes replace or replaced conditions which were chaotic. For example, the change over in France to the metric system, made now 150 years ago, was made at a time when the weights and measures of the country were in a hopeless condition; every province, every city, every hamlet had its own units and standards. Contrast this condition with that existing in the United States today.

In the United States in 1930, there is one gallon, for example, from Coast to Coast, and for five miles up in the air where airplanes range, and for a mile down where oil lies. One hundred and twenty-five million know and use the U. S. gallon, of 231 cubic inches,—they use it confidently, but probably 124,900,000 do not even know the 231 cubic inch equivalent. They do not have to. All U. S. gallons are alike; and the state weights and measures departments and the U. S. Bureau of Standards keeps them so. Here again, a U. S. gallon might become so many liters, cubic decimeters, but the public would never know the arithmetic of it, any more than they know the cubic-inch figure.

Each one of the eleven or so basic units we use in this country in a few million relations every day is similarly uniform throughout the land. True, there is some illogic connected with some of the units, but the public will not have anything else. We have for example two kinds of tons, so near alike that they have to be named "short ton" and "long ton" respectively. A hundred years evolution of our weights and measures has not eliminated either of these—and probably a thousand years will not either! The reason is plain to see. It may be ideal to have only one ton, but which shall be given the preference, and which shall be suppressed? If you suppress the long ton of 2240 pounds, then the millions of the poorer classes rebel since they buy all their coal in fractions of the long ton. If you suppress the short ton, then the railroads and the wholesalers disregard the order as they cannot figure other than in thousands of pounds. So there you are.

Weights and measures units, like other things, live as long as they are useful. They simplify and unify themselves automatically, and tend always to reduce their own variety to a minimum. This has actually happened in the United States, so much so that in many industries involving billions of dollars often only one or two units suffice for practically all measurements. In the automobile manufacturing industry, for example, the inch for all measurements of size and the pound for all weights are the only two units which have carried through and are needed today. In this industry alone, the "investment" in these two units transcends the investment in all the metric system units put together in any dozen so-called metric countries.

This article has no intention of putting up any argument for or against the use and advantages of the metric units themselves. There is no argument against such use and advantages. The kilogram, for instance, is the metric unit for trade weights. It is a perfectly respectable unit. Its value is known to a high degree of precision—and the constancy of the reference kilograms in the world—including that in the United States—is unquestioned. But the difficulty is that our people at large do not use the kilogram; and even those of "metric descent" who were brought up to use it and think in terms of it, can't buy butter, cheese and lard by it, so they do not use it now. Moreover, they evidently feel just as safe in buying butter, cheese and lard by the pound, for we have no reports from the grocery stores of customers requesting kilos.

Further, the scale manufacturers are all putting out their scales graduated in pounds, and these scales are today calibrated to a high degree of accuracy. The people have faith in them, and it may be said with probably a great deal of truth that our people today have much greater faith in the beautiful pound scales which the manufacturers now put out than they would have were new metric scales to appear suddenly on the counters of the grocery stores. It has required a great many years to take the uncertainties out of everyday weighing, and the stability and uniformity of the pound unit have done much to help create public confidence. The same thing could naturally have been done with the kilo, but the business has now gone too far, and would have to be started all over again. There would be upset confidence for many years, and apparently the small business men are not willing to take the risk. And—they know they do not need to.

And what applies for them applies everywhere. Unfortunately for any contemplated change to metric, we have achieved too great uniformity and too much standardization in what we have now. Standardization has been preached to us now for a great many years, and has become assimilated into practice to an unheard-of degree. It would have been unthinkable had not this principle of standardization been applied to the limit to our standards of measurement—of all things. We have achieved standardization in the values of our customary units, so that we now have practically no variations, and it is only with difficulty that one points to some little insignificant local custom or other which has carried over. These variations are conspicuous only by their unimportance.

Some would say that, this being the case, it would be easier now than at any time to change over the United States to metric. It certainly would be easier. This is the easiest time in the history of the country for making the change. But it is not being made, and this is the paradox. The people who could make the change do not want to do it; and the people who have nothing to gain or lose by the change, and who couldn't make it anyhow, want to do it. That is the perversity of human nature.

To touch on a spot right at home—if the editor will print the statement—the columns of INSTRUMENTS could be changed beginning with the next issue so that all designations of weights and measures in its columns were in metric units. *And it would cost nothing to make this change!* All the publications in the country could follow suit, and it would still cost nothing. Every workman in the country could within a very short time be supplied with all new metric tools, at a cost averaging probably not over $100 apiece, in the belief from the columns of INSTRUMENTS and other publications that the metric era had come.

And thereby the metric era might come a little nearer, but someone would make a slip and order a $\frac{7}{8}$ bolt; another a pound of putty; another a ton of coal; another five gallons of gas—and the present difficulties remain!

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

AIRCRAFT INSTRUMENTS. *C. J. Stewart.* Chapman & Hall, London, 1930. Cloth, 6x9 inches, 269 pages. Price $7.50.

A volume on aircraft instruments by Bennewitz in Germany was published in 1922, one in this country by Eaton and others in 1926, and now we have Major Stewart's volume featuring primarily British aircraft instruments. Major Stewart, by virtue of his official position, has had access to authoritative and complete information on the state and progress of aircraft instruments in Great Britain which he has utilized in an admirable manner. He is apparently not so well informed on present practice in the United States.

The arrangement of the book is good. There are fifteen chapters, three covering altitude and air speed measurements and instruments in considerable detail, four on power plant instruments, and one each on thermometers, inclinometers and other attitude instruments, compasses, navigating instruments, miscellaneous instruments, diaphragms, oxygen apparatus, and automatic control. There are two valuable appendices, one on the International Standard Atmosphere and one on the theory of the magnetic compass. The general discussion is quite satisfactory. However, the impression is obtained that no definite discrimination has been exercised as to the amount of space allocated to commonly used instruments and instruments still in the experimental or laboratory stage. Further, we fear, that the general reader will not be able, in a number of cases to distinguish clearly between these two types.

A few discrepancies of especial interest to American readers should be mentioned, which are, on the whole, of minor importance from the viewpoint of the reader seeking information on British instruments. The references to United States developments are sometimes inaccurate and invariably inadequate. As an example, a foreign make altimeter dated 1924 (undoubtedly American), one in production in England in 1924, and an experimental English instrument are selected for a comparison which turns out highly unfavorable to the instrument of foreign make. As a matter of fact, altimeters manufactured in the United States under military specifications of 1929 have errors which are about as small as those of the English experimental instrument making due allowance for difference in testing temperatures. Why give data as of 1924 in 1930? Also an erroneous impression is given of current practice in this country in measuring air speed, the text, page 62, implying that the pitot-venturi type is the standard. Aircraft instrument manufacturers, since about 1925, have been making only the pitot-static type air speed meter, the indicator of which contains metallic diaphragms. Contrary to the author's statement on page 233 non-metallic diaphragms for aircraft instruments have practically disappeared in the United States.

The coining of a new pressure unit, that of an inch of mercury at a temperature of 62°F and subjected to gravity at London, for use in testing altimeters in England is curious and is greatly to be deplored.

From the American point of view the discussion of the Northerly turning error of compasses is accorded too much space. The turn indicator-compass combination is invariably used here in "blind flying" instead of a compass alone, thus eliminating the importance of this error both in design and use of compasses.

The current Askania catalogue (1929) omits all reference to the distant reading compass described in the book but describes a new type instrument utilizing pneumatic instead of electrical transmission.

The figures, 198 in number, are well chosen, although a few of the photographs have been reduced more than necessary or desirable. The printing and paper are satisfactory, and typographical errors are very few in number. A more complete citation of references would be desirable in our opinion.

The book is highly recommended as a reference book for the instrument engineer. It is a source of information on British practice and covers in one volume the results of the very valuable instrument researches carried out by the Aeronautical Research Committee which are not always readily accessible to the American designer. In many cases it presents a point of view differing from our own and therefore instructive and stimulating. We do not think it will ever find favor as a text-book for American students or a handbook for the American flyer.—W. G. Brombacher & K. H. Beij.

Measurement of Air Flow

E. Ower, B.Sc. (Lond.), Hons.I., A.C.G.I.
Bramwell Medallist; Member of the Institution of Heating and Ventilating Engineers; Assistant in the Aerodynamics Department, National Physical Laboratory

CHAPTER V.

MEASUREMENTS OF FLOW AND RESISTANCE WITH PITOT-STATIC TUBES.

It was shown in the last chapter that the speed of flow at all points in a cross-section of a pipe is not in general the same, the velocity being a maximum at the centre and falling away towards the walls. Now instruments such as the combined Pitot-static tube or the vane anemometer will, of course, only indicate the local velocity in the regions which they occupy, so that in order to determine the volume of air flowing in unit time by the use of such instruments, it is necessary to measure the velocity at a number of points across a given section. Before we deal with the use of any particular instrument it will be well to discuss the problem from a general standpoint.

Determination of the Mean Velocity.—We shall, as before, define the mean velocity of flow v_m in the pipe as that velocity which, when multiplied by the area A of the pipe section, gives the volume V of air passing through the section per second.

If we consider a small element of area a_1 of the pipe through which the mean velocity of flow is v_1, the volume flowing through this element is a_1v_1, and

$$V = \Sigma a_1 v_1 = A v_m, \quad . \quad . \quad . \quad . \quad (1)$$

so that

$$v_m = \frac{1}{A} \Sigma a_1 v_1.$$

Suppose now that we divide the section of the pipe into n equal parts of area a, through which the mean velocities are v_1, v_2, v_3, etc., then we shall have

$$v_m = \frac{1}{A} \Sigma a v_1 = \frac{1}{A}(av_1 + av_2 + av_3 + \ . \ . \ . \ + av_n)$$
$$= \frac{a}{A}(v_1 + v_2 + \ . \ . \ . \ + v_n).$$

so that, since $A = na$,

$$v_m = \frac{1}{n}(v_1 + v_2 + \ldots + v_n). \quad . \quad (2)$$

We see therefore that the mean velocity of flow through the pipe is obtained by dividing the section into a number of parts of equal area and measuring the mean velocity through each. If the number of parts is sufficiently large, i.e. if each part is sufficiently small, the mean velocity through any part may be taken as the velocity of flow at its centre. The number of velocity readings necessary will therefore be equal to the number of parts into which the section is divided. It will be clear that the more irregular the velocity distribution across the section, the greater will be the number of parts into which the section must be divided, if the velocity measured at the centre of area of each part is to approximate to the mean velocity across that part. Further, if we consider two pipes, similar in section but different in size, and assume that the velocity distributions across any pair of corresponding sections are similar, then for the same percentage accuracy in the determination of v_m, the two sections must evidently be divided into the same number of corresponding parts. This point is often not appreciated; it must be remembered that if, for practical reasons, fewer measurements are taken in a small pipe, some accuracy will be sacrificed. The number of readings taken should depend primarily on the nature of the velocity distribution across the pipe, and not on the size of the pipe. At the same time, more readings should be taken in large pipes, unless the velocity distribution takes the form of a smooth curve, for the reason that if the points of measurement are too far apart, any local irregularities in velocity are liable to be passed over in the observations, and such irregularities are perhaps likely to be more important in large pipes than in small ones.

In considering how best to divide up a pipe section in practice, we need discuss only pipes of circular and rectangular cross-section, since it is exceptional to use sections of any other form.

(*a*) **Pipes of Rectangular Cross-section.**—The section should be divided, by lines parallel to the sides, into a number of equal areas each geometrically similar to the whole section (Fig. 21), and the velocity should be measured at the centre of each. The mean velocity and the volume flowing per minute can then be obtained directly by the use of equations (1) and (2). As regards the number of parts into which the section should be divided, a good working rule, subject to the remarks made above, is to make the minimum number 16 for pipes up to 576 square inches in cross-sectional area, and for larger pipes to take the number such that each part is not greater than 36 square inches in area. (For pipes of less than 5-inch side see remarks for small circular pipes.)

(*b*) **Pipes of Circular Cross-section.**—The pipe should be divided into n equal concentric zones with centres at O, as in Fig. 22, by circles of radii r_2, r_4, r_6, etc. If now we take any radius OP of the pipe, and consider a particular zone—AB say—a velocity measurement must be made along this radius at a point such that the circle through it with O as centre divides AB into two equal areas. The positions of the points of measurement in the other zones are determined in the same manner, and it will be evident that the whole section is in effect divided into $2n$ parts by circles of radii r_1, r_2, r_3, etc., and that n velocity measurements are made at the radii r_1, r_3, r_5 and so on, the outermost point of observation being r_{2n-1}.

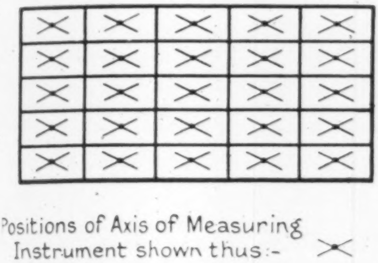


FIG. 21.

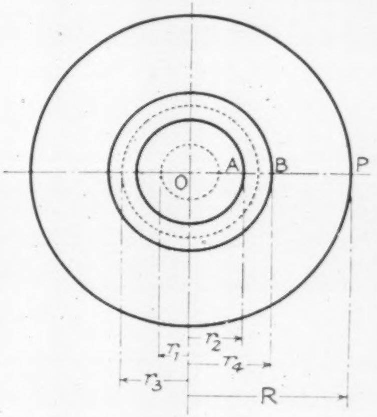


FIG. 22.

If R is the length of the radius of the pipe, the following equations express the conditions that all the zones are of equal area :—

$$\pi(R^2 - r^2_{2n-1}) = \pi(r^2_{2n-1} - r^2_{2n-2}) = \text{etc.}$$
$$= \pi(r_2{}^2 - r_1{}^2) = \pi r_1{}^2,$$

so that

$$r_2{}^2 = 2r_1{}^2,$$
$$r_3{}^2 = 3r_1{}^2, \text{ etc.},$$
$$r^2_{2n-1} = (2n - 1)r_1{}^2,$$

and

$$R^2 = 2nr_1{}^2.$$

Hence

$$r_1 = R\sqrt{\frac{1}{2n}},$$

$$r_2 = R\sqrt{\frac{2}{2n}}, \text{ etc.,}$$

and $$r_{2n-1} = R\sqrt{\frac{2n-1}{2n}}.$$

The n readings of velocity are therefore to be taken at radii $R\sqrt{\frac{1}{2n}}$, $R\sqrt{\frac{3}{2n}}$, $R\sqrt{\frac{5}{2n}}$, etc., the final radius being $R\sqrt{\frac{2n-1}{2n}}$.

In practice it is not sufficient to take readings along one radius only. The mean velocity for each zone should be obtained from four readings, one along each of four radii of which two form one pipe diameter and the other two the perpendicular diameter. It follows that $2n$ readings of velocity will be taken along each of the two chosen diameters, making a total number of $4n$ observations, and it will usually be found convenient to locate the positions of observation by measuring from one end of the diameter. Expressed in this way, the distances at which readings of velocity are to be taken will be

$$\frac{D}{2}\left(1 - \sqrt{\frac{2n-1}{2n}}\right), \frac{D}{2}\left(1 - \sqrt{\frac{2n-3}{2n}}\right), \text{ etc.,}$$

$$\text{up to } \frac{D}{2}\left(1 - \sqrt{\frac{1}{2n}}\right)$$

on one side of the centre of the pipe, and

$$\frac{D}{2}\left(1 + \sqrt{\frac{2n-1}{2n}}\right), \frac{D}{2}\left(1 + \sqrt{\frac{2n-3}{2n}}\right), \text{ etc.,}$$

$$\text{up to } \frac{D}{2}\left(1 + \sqrt{\frac{1}{2n}}\right)$$

on the other, where D is the internal pipe diameter.

The number of observations to be taken will be governed largely by the considerations set out above. The following practical rules will, however, be found to serve as a useful guide in most cases.

For pipes of 6 inches to 12 inches diameter, n should have the value 3, so that six readings of velocity will be taken along each of two mutually perpendicular diameters, at distances of 0·044D, 0·147D, 0·296D, 0·704D, 0·854D, and 0·957D from the inside wall of the pipe.

For pipes over 12 inches diameter, n should be not less than 5, when ten observations will be made along each diameter at distances from the wall of 0·026D, 0·082D, 0·147D, 0·226D, 0·342D, 0·658D, 0·774D, 0·854D, 0·919D, and 0·975D. In cases where the diameter of the pipe exceeds 3 feet, more than 5 points along a radius should be taken.

Special consideration is needed for the accurate measurement of the flow in small pipes of less than 6 inches diameter; this subject is discussed more fully in Chapter VIII.

The above rules for determining the number of areas into which pipes should be divided must not be regarded as rigidly applicable in all cases. They will be found to give reasonably accurate results provided that the velocity distribution across a diameter of the pipe follows a more or less smooth curve, but if any doubt is felt as to the nature of the distribution in a particular case, a preliminary exploration, comprising velocity measurements at a number of points in the section, should always be made. If the velocity distribution is found to be unduly irregular, and it is not possible to make measurements at some other section of the pipe where conditions are more favourable, there will be no alternative but to take a larger number of readings than the above rules indicate.

Measurements with Pitot-Static Tubes. — Measurements of velocity head must be made either by means of the combined type of Pitot-static tube or by means of separate total and static tubes inserted successively at the appropriate points as described below. In either case the resultant reading at each point of measurement will be a pressure p which is related, as we have seen, to the speed v at the point of measurement by the equation,

$$p = \tfrac{1}{2}\rho v^2, \quad . \quad . \quad . \quad . \quad (3)$$

where, if v is to be in feet per second, ρ must be expressed in slugs per cubic foot $\left(\dfrac{\text{pounds weight per cubic foot}}{g}\right)$ and p in pounds per square foot.

For air at a temperature of 15·6° C. (60° F.) and a pressure of 760 mm. of mercury (29·92 inches) $\rho = 0{\cdot}00237$, and for any other temperature t° C. and pressure b mm. of mercury,

$$\rho = 0{\cdot}00237 \times \frac{288{\cdot}6}{273 + t} \times \frac{b}{760}$$

$$= 0{\cdot}009 \times \frac{b}{273 + t}. \quad . \quad . \quad . \quad . \quad (4)$$

Usually, it is more convenient to measure p not in pounds per square foot but as h inches of water column, so that

$$h = p \times \frac{12}{62{\cdot}36} = 0{\cdot}1924p.$$

Hence if the velocity head h is expressed in inches of water

(3) becomes

$$h = 0{\cdot}0000866v^2 \times \frac{b}{273 + t},$$

or

$$v = k\sqrt{h}, \quad . \quad . \quad . \quad . \quad (5)$$

where

$$k = 107{\cdot}5\sqrt{\frac{273 + t}{b}}.$$

If t is measured in degrees Fahrenheit and b in inches of mercury, the corresponding value of k becomes

$$15{\cdot}88\sqrt{\frac{460 + t}{b}}.$$

Returning now to equation (2), we see that, when Pitot and static tubes are used to measure the quantity of air flowing in a pipe, the average velocity v_m is given by

$$v_m = \frac{k}{n}(\sqrt{h_1} + \sqrt{h_2} + \sqrt{h_3} + \ldots), \quad . \quad (6)$$

where h_1, h_2, h_3, etc. are the velocity heads observed at the points of measurement, whose positions are determined in the manner explained above. If we denote by h_m the velocity head corresponding to the average velocity we have, from (6),

$$\sqrt{h_m} = \frac{v_m}{k} = \frac{1}{n}(\sqrt{h_1} + \sqrt{h_2} + \sqrt{h_3} + \ldots); \quad . \quad (7)$$

i.e. the square root of the head equivalent to the mean velocity is equal to the arithmetic mean of the square roots of the velocity heads observed at the centres of zones of equal area.

The volume of air passing per second in cubic feet will be

$$\frac{Ak}{n}(\sqrt{h_1} + \sqrt{h_2} + \sqrt{h_3} + \ldots), \text{ or } Ak\sqrt{h_m},$$

and the weight of air, in pounds per second,

$$\frac{Ag\rho k}{n}(\sqrt{h_1} + \sqrt{h_2} + \sqrt{h_3} + \ldots), \text{ or } Ag\rho k\sqrt{h_m},$$

where ρ is obtained for the appropriate conditions of temperature and pressure from equation (4), and A is the area of the pipe in square feet.

In practice, engineers usually prefer to measure the flow in cubic feet V or pounds Q per minute. For these units we shall find

$$\left.\begin{aligned} V &= A \times 6450\sqrt{\frac{273 + t}{b}}\sqrt{h_m} \text{ cubic feet per minute,} \\ \text{and } Q &= A \times 186{\cdot}9\sqrt{\frac{b}{273 + t}}\sqrt{h_m} \text{ pounds per minute,} \end{aligned}\right\} \quad (8)$$

when temperature and pressure are measured in degrees Centigrade and millimetres of mercury respectively.

When the Fahrenheit and inches of mercury scales are used, these expressions become

$$\left.\begin{aligned} V &= A \times 953 \sqrt{\frac{460+t}{b}}\sqrt{h_m} \text{ cubic feet per minute,} \\ \text{and } Q &= A \times 1264\sqrt{\frac{b}{460+t}}\sqrt{h_m} \text{ pounds per minute,} \end{aligned}\right\} \quad (9)$$

It will be seen that the expressions for both V and Q involve a term containing $\sqrt{b}$, in one case in the denominator and in the other in the numerator, so that a 2 per cent. error in b will give rise to a 1 per cent. error in V or Q. Now there will, in general, be a static pressure p_s in the pipe, and according to the usual convention, which we shall adopt here and in subsequent chapters, this pressure is measured above or below the atmospheric pressure p_a*. The absolute static pressure of the air will thus be equal to $p_s + p_a$, and this is the quantity we have denoted by b in equations (8) and (9). The average barometric pressure p_a may be taken as roughly equal to 400 inches of water, so that unless the measured static pressure p_s in a particular case numerically exceeds 8 inches of water, we may neglect it in comparison with the atmospheric pressure p_a without causing an error exceeding 1 per cent. in V or Q. It follows that in a large number of cases b in the above formulæ can be taken as the barometric pressure p_a without sensible error. If, however, greater accuracy is required than is afforded by this assumption, b must be taken as equal to p_a plus or minus the static pressure p_s, according as the latter is positive or negative. In making this correction it should be remembered that p_s is usually measured in inches of water whereas b is to be expressed in millimetres or inches of mercury according as formula (8) or (9) is being used. For (8) p_a must be increased or diminished by $\frac{p_s}{13{\cdot}56 \times 25{\cdot}4}$, i.e. by $0{\cdot}0029p_s$, and for (9) by $\frac{p_s}{13{\cdot}56}$ or $0{\cdot}074p_s$.

Summary of Procedure for Measuring Quantity with Pitot and Static Tubes.—From the foregoing we may summarise as follows the procedure to be followed in obtaining by means of Pitot and static tubes the quantity of air flowing in a pipe of cross-sectional area A square feet:—

(1) Measure the velocity head in inches of water at a number of points across the section, determined in the manner

---

* According to this convention when the static pressure is said to be zero, the air is actually at atmospheric pressure.

already indicated, which are at the centres of zones of equal area.

(2) Determine the square root of each velocity head and divide the sum of the square roots by the number of observations. In this manner the square root of the head equivalent to the mean velocity is obtained.

(3) Denoting the head equivalent to the mean velocity by h_m, as above, calculate the quantity flowing by the use of the following formulæ :—

$$\left.\begin{aligned} \text{V (cubic feet per minute)} &= \text{C}_1\text{A}\sqrt{h_m}, \\ \text{Q (pounds per minute)} &= \text{C}_2\text{A}\sqrt{h_m}, \end{aligned}\right\}^{*} \qquad (10)$$

where C_1 and C_2 are numerical factors depending upon the temperature and pressure.

If the temperature t is measured in degrees Fahrenheit and the barometric pressure b in inches of mercury,

$$\left.\begin{aligned} \text{C}_1 &= 953\sqrt{\frac{460+t}{b}}, \\ \text{and } \text{C}_2 &= 1264\sqrt{\frac{b}{460+t}}, \end{aligned}\right\} \qquad (10a)$$

whilst for the Centigrade and millimetres of mercury scales these coefficients become

$$\left.\begin{aligned} \text{C}_1 &= 6450\sqrt{\frac{273+t}{b}}, \\ \text{and } \text{C}_2 &= 186{\cdot}9\sqrt{\frac{b}{273+t}}, \end{aligned}\right\} \qquad (10b)$$

(4) The quantity b may be taken as the observed barometric pressure so long as the static pressure in the pipe does not exceed 8 inches of water.* Otherwise b must be increased or diminished by the static pressure, expressed in inches or millimetres of mercury according to the units in which the barometric height is observed. The conversion factors are given above.

When air measurements have frequently to be made it will probably be found useful, in order to save numerical calculation, to prepare charts from which the coefficients C_1 and C_2 can be read off directly. A specimen chart, suitable for cases in which a wide range of temperature is to be covered by the observations, is shown in Fig. 23. It will be seen that values of C_1 and C_2 determined from equations (10*a*) are plotted for values of b of 29, 30, and 31 inches of mercury, so that the value of C_1 or C_2 for any temperature within the range covered by the chart is given by the ordinate of the appropriate curve. Values for intermediate pressures can be obtained with sufficient accuracy by interpolation, and for pressures over 31 inches or under 29 inches (both of which are of infrequent occurence) by extrapolation.

---

* Note that $\sqrt{h_m}$ is obtained directly from § 2 of this summary.

Measurement of the Mean Total Head at a Section of a Pipe.—It was shown in Chapter IV. that the resistance of a length of pipe between any two sections A and B to the flow of air along it may be expressed as the difference between the true mean total heads T_1 and T_2 at A and B. It was also shown that if v is the velocity at a section of a circular pipe at radius r, and R is the internal pipe radius

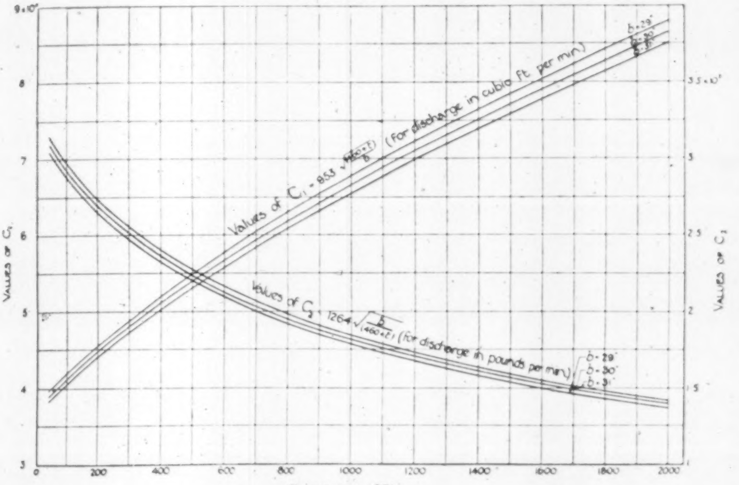


FIG. 23.

$$T = \frac{1}{2}\rho \frac{\int_0^R v^3 r dr}{\int_0^R v r dr} + \frac{\int_0^R p v r dr}{\int_0^R v r dr}. \qquad (11)$$

In order, therefore, to determine T the value of each of the integrals in (11) must be calculated. For the highest accuracy p and v should be measured at a sufficient number of radii to enable curves showing the variation of v and p with r to be defined. From these data it is possible to obtain, at each value of r, values of the quantities v^3r, vr, and pvr, and to plot them against r. The areas enclosed by the curves thus obtained and the axis of r will be equal respectively to

---

* Without causing an error ot more than 1 per cent. in V or Q.

$$\int_0^R v^3 r dr, \quad \int_0^R v r dr, \text{ and } \int_0^R p v r dr.$$

The value of T from (11) is then calculable.

Some care is necessary with regard to the units. Usually v at each point will be determined from Pitot and static observations (in some cases possibly by means of an anemometer), and will be expressed in feet per second. The first term of (11), which we may call V, will thus have the dimensions of $\frac{1}{2}\rho \times (\text{velocity})^2$, i.e. of a pressure in pounds per square foot. In evaluating the second term (which we will denote by P) each value of v in feet per second may be multiplied by the observed value of the static pressure p in inches of water, for the integral in the numerator ; when this is divided by the integral in the denominator in which v is in feet per second, the resulting value of P will be in inches of water. Hence for the total head T to be expressed in inches of water, the value of V must be converted to these units, and since a pressure of 5·2 pounds per square foot corresponds very closely to 1 inch of water, we have

$$T = \frac{V}{5 \cdot 2} + P \text{ inches of water.}$$

This method is laborious and usually unnecessarily so. In most cases it will be sufficient to observe v and p at the centres of zones of equal area, just as in determining the mean velocity v_m in order to calculate the volume flowing. As a rule, in fact, the observations of velocity head taken for the determination of v_m, supplemented by measurements of p at the same points, may be used for calculating T. We shall then have a number of velocity heads h_1, h_2, h_3, etc., taken at points chosen in accordance with the rules laid down on page 55, and a number of static pressures p_1, p_2, p_3, etc., at the same points. The simplest procedure will then be to determine the velocities v_1, v_2, v_3, etc., corresponding to these velocity heads. It is then easy to show that

$$T = \frac{1}{5 \cdot 2} \times \frac{1}{2}\rho \frac{v_1{}^3 + v_2{}^3 + v_3{}^3 + \ldots}{v_1 + v_2 + v_3 + \ldots} + \frac{p_1 + p_2 + p_3 + \ldots}{n},$$

where n is the total number of static pressure readings taken. It is here assumed that the static pressure does not vary much across the section. If it does the flow is not everywhere parallel to the axis of the pipe. When the departure from axial flow is very pronounced it is doubtful whether any method of measurement will give good accuracy, since both v and p as measured at any point may be in error on account of the inclination of the local direction of flow to the Pitot and static head. An attempt should always be made to avoid the necessity for taking measurements at such sections, but if there is no alternative, the second term in T should be obtained from the expression

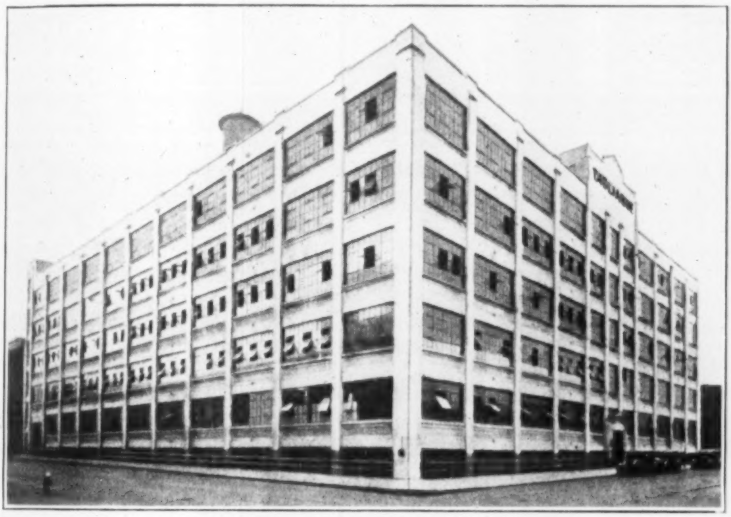
$$\frac{p_1v_1 + p_2v_2 + p_3v_3 + \dots}{v_1 + v_2 + v_3 + \dots}$$

instead of that given above.

The modification of these methods to suit pipes of rectangular section follows simply on the lines of the measurement of v_m for such sections (see page 284) and needs no further comment.

* * *

The C. J. Tagliabue Manufacturing Company announce the acquisition of the American Tobacco Company property on Park Avenue, extending from Nostrand Avenue to Sanford Street in Brooklyn, N. Y. The Tagliabue Company has been industrially prominent in Brooklyn for many years and in moving from Bush Terminal, its present location, another great stride in its progress is apparent.



TAG industrial and laboratory instruments are known and used the world over. Among these should be mentioned indicating, recording and controlling instruments for temperature, pressure, humidity, time, condensation and liquid level, laboratory and industrial thermometers, hydrometers and oil testing instruments. The late C. J. Tagliabue devoted his life to the manufacture and distribution of scientific instruments to measure the important properties of oil. Under his guiding hand, oil testing instruments were developed from crudely constructed home made affairs to devices of great refinement and precision. Not alone the oil industry but every basic industry operates more effectively, with greater precision and with less waste because of the contributions Tagliabue has made and is making in the field of industrial control by means of instruments.

From a great manufacturing plant in Bush Terminal, the company enlarges to more than double its present facilities in its projected removal to Park Avenue. The new building, a model of the latest industrial construction, will be occupied about the first of July. It is a five story, basement and pent house, modern concrete, fire-proof structure covering the entire block front on Park Avenue, from Nostrand Avenue to Sanford Street. The plot measures 200 x 234 feet and the building provides approximately 300,000 square feet of working floor space with lofty 14 foot ceilings and modern steel sash making it unusually light.

Scientific arrangements have been made in planning the various manufacturing departments. From the point of introduction of raw material to the completion of finished products, efficient, mobile, straight-line production has been the watchword.

Located on the third floor, the executive offices will command a centralized approach to every department. A large reception room and show room are provided on this floor where permanent exhibits of TAG products will be on display.

That the well being, comfort and health of employees is a prime consideration of the Tagliabue management is evidenced by the restaurant and hospital facilities which will be provided. A large modern cafeteria will be located on the third floor for the general office and factory employees. The completely equipped hospital is to be conveniently located on the first floor, easily accessible to the entire plant.

The general location of the building itself is fortunate as it is within easy accessibility of rail centers and steamship docks. Two large loading platforms under cover and a rear drive-way running from Nostrand Avenue to Sanford Street offer every facilitity for rapid transportation.

The laboratories and experimental divisions have been given a generous allottment of space which they well deserve. Here, are perfected the instruments and devices that help to make better tires for your car, better gas and oil for its motive power, safer milk, canned fruits and vegetables for your table and processed silks.

* * *

The Claud S. Gordon Company of Chicago announce the purchase of all the physical assets, good will, patents, etc. of the Cleveland Instrument Company, Cleveland, Ohio, and the General Pyrometer Supply Company, Cleveland, Ohio. The Claud S. Gordon Company will operate the new consolidation under the name of Pyrometer Service and Supply Corporation, and will be located at 1988 East 66th Street, Cleveland, Ohio. This new Ohio corporation will take over all the service, repairs and supply business of both the old companies and also the Price Instrument Company's service and supplies in the Cleveland district.

We regret to announce the death of
Mr. Robert M. Adams, Sales Manager
of the Amthor Testing Instrument Company, Inc., on April 14th, 1930

Measurements

Industrial & Scientific

An Instruction Book for Engineers

DR. WALTER BLOCK

Eichungsdirektor der Provinz Ostpreussen

CHAPTER XIII. TEMPERATURE MEASUREMENTS

1. General

The standard temperature scale on which all thermometric measurements are based at present, is the so-called thermodynamic scale of one hundred divisions which agrees practically with the familiar Celsius scale. As is well known, the melting point of ice is designated as temperature of 0°; it may be mentioned here that this temperature is realized in practice by a mixture of cracked ice and pure water for which, with very few exceptions, commercial ice will do, but mixed with so much water that a slushly mixture is formed. The boiling point of water at a pressure of 760 mm Hg (measured not in the water but in the water vapor formed by it so that its temperature is independent of impurities in the water) is designated as 100°. A table is given below showing the change of the boiling point of water with change of barometric pressure.

Barometer Reading	Boiling Point	Barometer Reading	Boiling Point	Barometer Reading	Boiling Point
680	96.92°	720	98.49°	760	100.00°
2	97.00	2	57	2	07
4	08	4	65	4	15
6	16	6	72	6	22
8	24	8	80	8	29
690	32	730	88	770	37
2	40	2	95	2	44
4	48	4	99.03	4	51
6	56	6	10	6	58
8	63	8	18	8	66
700	71	740	26	780	73
2	79	2	33		
4	87	4	41		
6	95	6	48		
8	98.03	8	56		
710	11	750	63		
2	18	2	70		
4	26	4	78		
6	34	6	85		
8	42	8	93		

The thermodynamic scale uses, for the fixation of the temperature scale with these two points, a so-called perfect gas, i.e., a gas which obeys the elementary laws of gases actively and in its whole range. If such a gas, which is not fully realized by most actual gases, has at two temperatures T and T_1 under the same pressure the volumes v and v_1 or, at the same volume the pressures p and p_1 respectively, the simple relation

$$\frac{pv}{T} = \frac{p_1 v_1}{T_1}$$

should hold. As will be seen, if two points are determined numerically in the temperature scale, then the temperature of each intermediate point is unequivocally fixed numerically. In practice the case is such that all gases at our disposal do not strictly follow the laws of gases but show certain unimportant deviations. Hydrogen and helium come very close to the ideal gas. The deviations from an ideal gas can be experimentally determined. (For details the reader is referred to treatises on physics, where more exact information on this subject is given.) This can be done by means of an experiment which is known as the Joule-Thomson experiment, permitting the gas to escape under high pressure from a small nozzle and experimentally determining the changes in gas temperature in the course of the flow through the nozzle. From the results of such tests the deviations of such gases from the perfect gas can be determined numerically.

From the foregoing it follows directly that the fundamental apparatus for measurements of temperature is the gas-thermometer, in other words a thermometer which uses the changes of volume or pressure of a gas for the measurement of temperature. Diagrammatically, therefore, a gas-thermometer of equal volume will look somewhat like that shown in Fig. 69. A glass bulb is exposed to the temperature to be measured and is closed to the outer air by a U-tube filled with mercury. The gas in the bulb will expand or contract and will change the level of the mercury in the U-tube. At the mouth of the bulb the mercury is brought into contact with a fixed point, for instance a glass tip fastened to the tube, by means of a mercury container which can be adjusted, or by a corresponding movement of the tube which is provided with a rubber hose at the bottom. One then works with the so-called gas-thermometer with constant volume. The height of the mercury column is determined and the same tests are repeated at the temperatures 0° and 100°, i.e., by imbedding the glass bulb in melting ice and placing it in water vapor respectively. These two measurements which fix the points 0° and 100°, and the level of the mercury compared with the two levels at the standard points permits determining the temperature.

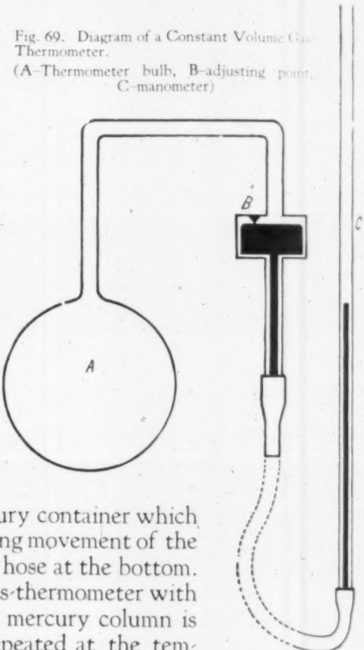


Fig. 69. Diagram of a Constant Volume Gas Thermometer.
(A-Thermometer bulb, B-adjusting point, C-manometer)

Practically the gas-thermometer is of little importance as it is much too complicated in its application. It is, however, very often used in scientific laboratories which have been entrusted with the task of fixing and maintaining the temperature scale.

Supplementing the foregoing it may be said: The two above mentioned fixed points of temperature are in principle sufficient for all thermometical work by applying the above defined thermodynamic scale which in earlier publications is still called the "International hydrogen scale"[1]) which is not identical with the former as it uses hydrogen instead of a perfect gas, but which in fact agrees with the former within such narrow limits that the differences are almost entirely negligible. Besides those fixed points, a series of other thermometric fixed points has been empirically determined with the gas-thermometer, giving the so-called secondary fixed points which are quite useful for many thermometric investigations as with them the exact values of temperatures and the accuracy of temperature measuring methods can be checked. For such *thermometric fixed points* there are used: first, some melting points, especially of metals, then some freezing (solidification) points, and, lastly (although practically in only one case) transition points, that is the point at which a substance passes from one moleculcar modification to another one. This point can be determined i.e., for sodium sulphate by having heat supplied gradually; a thermometer placed into such solution will show a uniform increase. As soon as the molecular change takes place the additional heat supplied is consumed for this change so that, for a time, the thermometer remains unchanged which proves that then the transition point has been reached. After that the thermometer will again rise regularly. These important points are listed in the following table:

---

[1])This scale is also applied in the definitions for the fundamental units of the metric system. In the temperature range under consideration here the departures from the thermodynamic scale are entirely negligible.

THERMOMETRIC FIXED POINTS

(according to Henning, Handbuch der Physik; Vol. IX, page 600)

(F.P. = freezing point, M.P. = melting point, B.P. = boiling point at 1 at., Sb = Sublimation point at 1 at., T.P. = transformation point).

Hydrogen	B.P.	— 252.78	Benzo phenon	B.P.	+ 305.9
Nitrogen	B.P.	— 195.81	Cadmium	F.P.	+ 320.95
Oxygen	B.P.	— 183.00	Zinc	F.P.	+ 419.45
Ethyl ether, in stable form	F.P.	— 123.5	Sulphur	B.P.	+ 444.60
Carbon Bisulphide	F.P.	— 112.0	Antimony	F.P.	+ 630.5
Toluol	F.P.	— 95.0	Silver	F.P.	+ 960.5
Carbon dioxide	B.P.	— 78.51	Gold	F.P.	+1063
Chloroform	F.P.	— 63.5	Palladium	F.P.	+1557
Chlorobenzol	F.P.	— 45.6	Platinum	M.P.	+1770
Mercury	F.P.	— 38.87	Molybdenum	M.P.	+2620
Sodium sulphate	T.P.	+ 32.38	Tungsten	M.P.	+3380
Naphthalene	B.P.	+ 217.96	Carbon	M.P.	+3490
Tin—	F.P.	+ 213.85			

2. MERCURY THERMOMETERS

The usual thermometer employed for most chemical work is the familiar mercury thermometer, as well as special types (which will not be considered here) in which the mercury is replaced by other liquids, such as alcohol or, for low temperatures, pentane. As is known, mercury thermometers cannot be used below about —35°C as mercury freezes at this point. The upper limit depends largely on the kind of glass used. The point, 700°C, can be considered as upper limit.

In the construction of a thermometer, it must be remembered that all the materials used also change their volume with temperature changes. If, therefore, different thermometers are made for which the points 0 and 100° have been fixed experimentally it could be assumed that the problem has been solved. However, this is not so because it has been found from experience that the expansion of the liquids does not take place uniformly, and further, that these liquids are in glass containers which likewise expand with temperature, and also that this expansion is not uniform. It is, therefore, necessary, to make the divisions between the zero point and the 100-degree point not exactly uniform but such as to take into consideration the non-uniformity of expansion of the thermometer liquid and of the thermometer glass, provided that the capillary of the thermometer is perfectly cylindrical.

For the thermometer maker, however, the matter is, in fact, simpler. The thermal properties of different thermometer glasses and thermometer liquids have been determined very often so that it is possible if a cylindrical capillary is assured to determine numerically and, therefore, to take into account the departure of the divisions from uniformity. In fact, the manufacturer of thermometers proceeds in such manner that, instead of this procedure, several "points" of the thermometer being made are determined by using suitable standard thermometers and temperature baths. If a standard mercurial thermometer is to be made, this procedure cannot be employed and a standard gas-thermometer must be resorted to.

There is little to be said on the form of the well-known mercury thermometer. In principle, two types of thermometers are distinguished, both possessing advantages and disadvantages, namely the so-called rod-thermometers and the inclusion thermometers. The rod thermometers are generally made of a cylindrical glass tube with a capillary in the interior, and the graduations are marked on the outside of the tube. Such thermometers generally have a small section, are quite handly, but also somewhat fragile. In the inclusion thermometer, capillary and scale are separated from each other, and both are enclosed in a separate tube which protects them. The thermometer, therefore, takes up more space, is more resistant to breakage, but offers certain difficulties with regard to the mounting of the scale in relation to the capillary. In reference to heat measurement, both can be considered as equivalent.

If thermometers of greater accuracy are required it is necessary to make them up with scales covering only a small portion of their ranges. Very often, therefore, the capillary proper is interrupted by suitable expansions, which results in the temperature scale being interrupted to a certain extent. For instance, a thermometer is provided with a short scale near 0°, then the capillary is expanded, and then only follows the actual scale from, say, 50 to 100°. An enlargement of the capillary is located at its end where it is melted off. This expansion at the top prevents the bursting of the thermometer when heated slightly above its highest temperature.

Another special form may here be mentioned, the so-called Beckmann thermometer. This is a thermometer which, contrary to the usual ones has only a very limited range but is, particularly sensitive within this range. The graduations of the usual thermometers are whole degrees and, in finer thermometers, fifths or tenths of a degree. The length of the scale of the thermometer is usually so dimensioned that the smallest interval between divisions is not less than about 0.6 mm, so that, for the finer types, each degree has a length of 6 mm. From this, the length of the finished thermometer can be calculated if the required range is known, and where it must be taken into account that the thermometer does not become too long and therefore fragile. For Beckmann thermometers in general a graduation of one hundredth of a degree is provided; the range covers a few degrees only, and besides, they are made in such manner that the amount of mercury present is not dimensioned to indicate a certain temperature. They only serve for the measurement of temperature differences while the adjustment for absolute temperature is made by comparison with another thermometer.

To illustrate: For the purpose of determining molecular weight, decreases of freezing points are to be observed. The amount of mercury in the thermometer is then so dimensioned that the Beckmann thermometer

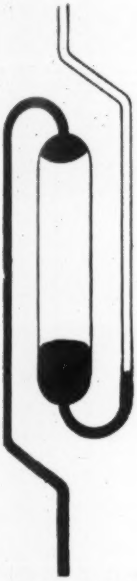


Fig. 70. Device for Seperating Mercury from the Thread of Beckmann Thermometers.

in the solution indicates immediately below its upper end when it freezes. The whole scale is then available for the decrease of the freezing point. In order to adjust the thermometer to any temperature range the capillary is provided with a suitable shaped expansion (Fig. 70) which can hold larger amounts ofmercury and store it in such manner that it cannot again directly join the principal quantity of mercury. This can be done in the manner illustrated by bringing over part of the mercury into this enlargement and separating it there.

As regards the quality of Beckmann thermometers it may be said that they are very often somewhat overrated. First, it must be mentioned that in order to obtain the necessary sensitivity with the usual capillary diameters as are practicable, considerable amounts of mercury are required for the thermometer bulb. From this follows that the thermometer becomes rather inert, considerably more so than other thermometers, and requires a longer time for equilibrium. Further, it may be pointed out that it is rather difficult to determine whether the value of one degree of such a thermometer is really correct. With usual thermometers this can hardly be done in a practical way as they are at least one-tenth as sensitive as the Beckmann thermometers. It can therefore be done only by a large number of tests, which is rather tedious. Finally, one must consider that only a part of the mercury in the thermometer is employed. Though very small amounts are involved it is not quite without influence because the length of a degree can be fixed only for a definite mass of mercury in the principal bulb. If this mass is changed it is impossible that the length of a degree remain correct. This is particularly true if the Beckmann thermometer is used for fairly high temperatures, that is, if the amount of mercury separated is comparatively large. The probable error in an individual case cannot be stated with certainty as it varies from case to case. The same of course holds true for all thermometers if as is sometimes done, part of their mercury is separated in order to use them for other temperature ranges.

Concerning other forms of the mercurial thermometer, a little can be said: In particular the shape of the bulb is selected so that it has a large surface because then the exchange of heat with the surroundings takes place the quickest. High-grade thermometers, in contrast to the ordinary ones which are made up with a vacuum above the mercury thread, are filled with a chemically neutral gas, in particular nitrogen, in order to raise the boiling temperature of the mercury. The sealing of these thermometers is done under pressure at room temperature; and at high temperatures there is a very considerable pressure in the interior. This may even cause an explosion if handed carelessly, but in particular there is danger that the thermometer bulb will be overheated when working carelessly, and then the pressure in the interior of the thermometer expands the bulb more or less, which naturally causes entirely erroneous indications.

Another circumstance has to be observed when measuring higher temperatures. It easily happens that some of the capillary mercury distills off towards the upper end and there condenses, so that the mass of mercury used for measuring is reduced slightly. This also causes a lower thermometer reading. It is, of course, always possible to run the mercury into the bulb again, uniting the two quantities and thus to correct the thermometer.

For temperatures below the freezing point of mercury, liquid thermometers with alcohol, toluol, or pentane are used. Working with such thermometers is not simple if reliable results are desired as all these liquids are bad heat conductors. It therefore takes a long time before the final temperature equilibrium is obtained, much longer than with the metallic mercury. Further, these liquids adhere to the wall of the capillary if they are cooled strongly, especially as they then become rather viscous, and flow along the wall very slowly. This disadvantage is avoided by first exposing only the bulb to the low temperature so that the liquid in the capillary still remains for some time considerably warmer, and only when the thermometer has assumed its proper level is the liquid in the capillary permitted to cool down. Due to the non-uniform expansion of these liquids the scale does not have a uniform graduation as do mercury thermometers.

The precision readings of thermometers are not made with the naked eye. When using precision thermometers, the position in which they are used is important. The vertical position is most likely the proper one, however the horizontal is necessary in many cases. Due to the elasticity of glass the pressure in the interior of the thermometer is quite different in these two positions. A vertical thermometer must, for the same temperature, indicate less than when laid horizontal, because then the pressure of the mercury column, which causes a slight expansion of the bulb, is eliminated. The same, of course, holds true if the thermometer is placed in a container and rigidly connected to it, while there is pressure in the container. This compresses the bulb of the thermometer a little and makes it indicate too high — how much must be determined in each individual case. The reading of the inclusion thermometer is comparatively simple because here mercury meniscus and scale are close together. If one looks at the thermometer perpendicularly with the naked eye or a magnifying glass no noticeable errors in reading are observed. With rod-thermometers however, the reading is a little more difficult because here meniscus and scale are a few millimeters apart. More care must therefore be taken to sight perpendicularly to the axis of the thermometer. The simplest is, of course, to read with a magnifying glass mounted vertically on the thermometer. If this vertical mounting is difficult it is quite simple to turn, the thermometer 180° around its axis after the reading, and to read again, in other words to read with the scale in front and the scale behind. The mean value of both readings must then be absolutely correct. Of course, the thermometer must not be moved in the direction of its axis. In many cases it is sufficient to place a piece of mirror behind the thermometer and to hold the eye so that it appears in the mirror at the level of the meniscus.

If the thermometer today belongs among the best developed instruments it is due particularly to the fact that the properties of thermometer glasses have been investigated very carefully. The usual kinds of glass which serve for the manufacture of other glass apparatus are entirely unsuitable for the better thermometers. For these only certain types of glasses are used, in particular two kinds from the glass works Schott & Co., in Jena may be mentioned, the thermometer glasses 16^{III} and 59^{III} which both are quite different in their properties but thermometrically can be considered as about equivalent. Besides these other kinds of glasses are of some importance, for instance 1565^{III}.

If one has to test a thermometer in order to obtain a certification of its accuracy one must first make sure that the glass has become stable. No thermometer can be used for close measurements immediately after its manufacture, because of the elastic properties and elastic after-effects of glass. The bulb of the thermometer which during blowing was exposed to fairly high temperatures (that is at least to the softening temperature of the glass) changes its volume gradually and thus modifies the indications of the thermometer. For this reason, in all good factories a thermometer is first aged, that is to say it is subjected to a certain heat treatment before it is finally finished in order to eliminate these after-effects as much as possible. It is, however, impossible to eliminate them completely, and it can still be observed even in good thermometers that their fixed points rise gradually. In other words such thermometers do not indicate 0°C in melting ice but a somewhat higher temperature. This phenomenon practically never stops but continues for decades. Aging can only reduce it to a certain minimum.

Regarding the determination of the freezing point, it has already been mentioned how the ice mixture is to be made. In using a mercury thermometer, care must be taken that the whole mercury column is cooled down to zero. It is well to imbed the thermometer deeply in the ice and bring it up carefully for reading. The same holds true for the observation of the boiling point for which a suitable apparatus is shown in Fig. 71. The relation of the boiling point of water to barometric pressure can be represented by a formula $t = 100° + .0375\ (b - 760 \text{ mm})$.

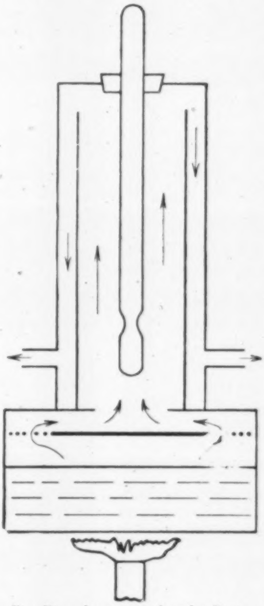


Fig. 71. Apparatus for the Determination of the Boiling Point of Thermometers.

It has been mentioned how the position of the thermometer influences its indications and how also exterior pressure can falsify the readings. Without special tests the exact magnitude of this source of error cannot be determined, but the so-called pressure coefficient serves to determine it roughly. Approximately, an increase in pressure of 1 mm Hg corresponds to about $^1/_{8000}°$. This figure can be used when pressure acts on the thermometer, either from outside or inside, and the same holds for the difference between vertical and horizontal position of the thermometer. For instance, a 300 mm thermometer will show a maximum difference of 0.04° between vertical and horizontal position.

It has been pointed out that glass is rather unsuitable thermometrically. This fact can be observed also in the permanent use of thermometers. If a thermometer is heated its bulb reaches its new final volume only after a longer time than it takes for mercury, and the thermometer will read too high. If the thermometer is then cooled off again, it arrives at the lower temperature with too large a bulb volume, and a depression of the zero point takes place. For this reason it is necessary to determine the stable ice point of a thermometer not directly after a heating but before. For exact temperature measurements this phenomenon must be properly taken into account. In order to be able to judge the quality and invariability of a thermometer one can therefore proceed in the following manner: The determination of the stable ice point, especially after accidental over-heatings, requires considerable time since one has to wait several hours. This checking of the invariability of a thermometer can, however, also be effected by observing always only the maximum depressed ice point, that is by heating the thermometer for about one half hour to 100° and then immediately bringing it into ice and then determining this point. All good thermometers should lend themselves to the definite location of the ice point because this is the only point which permits checking the gradual increase of the indications of the thermometer without trouble. Every thermometer that has no ice point must therefore be considered a second rate thermometer.

If one works at about room temperature the depression of the ice point becomes unimportant after heating, and can be left out of consideration. But it is quite different if one works over a larger temperature range. In this case one works with a depressed ice point: i.e., if a thermometer is exposed to a certain higher temperature which is to be measured, and is placed immediately afterwards into ice, the readings for the higher temperature are then counted from this ice point so determined. If one has read for instance any higher temperature, and immediately afterwards an ice point of −0.11° is found, the temperature read is to be increased by 0.11°, If, on the contrary the depressed ice point lies at 0.04° the temperature read must be reduced by 0.04°. This apparently tedious procedure can however be simplified satisfactorily for more exact measurements. At first the stable ice point is determined permanently for such a thermometer, i.e., perhaps once every year the ice point is determined when the thermometer has been near 20°C for many hours. For each thermometer reading the ice point correction must then be applied in exactly the same manner as described before, and after that, the temporary depression after heating of thermometer is determined once for all, i.e., after determination of the stable ice point the thermometer is heated for a certain length of time to, say, 100°, the depressed ice point is determined immediately, and in this way the difference of the ice point after 20° from that after 100° is at once established. If then any other temperature is measured the depression to be expected can be calculated and applied. This simple method though not quite strictly correct proves sufficient in practice even for stringent demands of accuracy.

An example will illustrate:

Stable ice point of the thermometer (after days at about 20° room temperature)	+0.02°
Ice point after ½ hour heating to 100°	−0.03°
Depression therefore 0.05° for heating from 20° to 100°	
Temperature read	80.15
Ice point (stable)	+0.02
Depression $0.05 \frac{60.15}{80} =$	0.04
Depressed ice point therefore	−0.02
Corrected reading	80.17

A disagreeable source of error in finer thermometric work arises from the occasional impossibility of exposing the entire thermometer to the temperature to be measured. This cause of error is called the emergent stem error. All thermometers are without exceptions graduated for total immersion of mercury. Another kind of manufacture would hardly be possible. But if a portion of the thread is at a different temperature, the entire mass of mercury does not have the temperature to be measured, and the thermometer will indicate too low, if the temperature to be measured is higher than the room temperature. Considerable difficulties are encountered in determining with sufficient accuracy the average temperature of the exposed thread.

To determine the value of the necessary corrections one must consider that the apparent expansion of mercury in thermometer glass has the following values:

Glass 16^{III}	0.000158
59^{III}	164
1565^{III}	172
Quartz Glass	180

Consequently, to the thermometric reading of t degrees the following correction must be applied: $d \cdot a \cdot (t - t_0)$, where d is the proportionality factor given above, a the length of the emergent thread expressed in degrees, t the temperature read, and t° the mean temperature of the emergent thread. With this formula the correction can be approximately calculated if one has an opinion what the temperature t_0 is in reality. Naturally it is best to keep a as small as possible or to make it equal to zero, that is to expose the thermometer fully to the temperature or to lift it a little for reading. A comparatively good mean temperature of the thread is arrived at in a manner suggested by Mahlke[2]), namely by using an auxiliary thermometer the bulb of which has the shape of a thread, and that of a length about the same as that of the exposed thread. This condition can be realized in practice only when one can count on an approximately constant length of thread. Otherwise one will have to be satisfied with arranging the ordinary thermometer in about such a position that its bulb is at the middle of the thread. It is evident from the foregoing that the corrections can assume, in many cases, considerable values, and that it is difficult to determine them with sufficient reliability. Special care must, therefore, be taken under all circumstances to keep them as small as possible.

In the following, there will be discussed briefly how an opinion can be formed as to the accuracy of a thermometer. The normal way is to rely entirely on the manufacturer, or, which offers no particular difficulties, to check the ice point and the boiling point of the thermometer as described above. If now the intermediate points are to be checked for accuracy either an officially tested standard thermometer is used or the bore of the thermometer can be calibrated. For this purpose it is necessary to break off threads from the principal mass of the mercury, to shift these within the capillary and to check in this manner the variations in the caliber of the bore over the length of the scale, as it is a matter of course that the bore will not be strictly cylindrical, but rather to be expected, according to the manner of manufacture, that it will be conical over certain stretches.

For such calibration the thermometer must not contain air. If it is suspended upside down part of the mercury in the capillary can be separated. Very often, however, the whole mass of mercury will flow from the bulb downward without thread separation. With some patience one can succeed, by suitable tilting, in having the vacuum bubble rise in the bulb to the mouth of the capillary and cause there the separation of a thread in the capillary. After the first time it is comparatively easy to cause the mercury to again separate at this same place. Apparently a microscopically small air bubble attaches itself here, and moves away only with difficulty. If the separated thread is longer than desired, the superfluous part of it may be allowed to run back over this place and join the other mercury, and then separated again at this place. However, it is better to note the spot of separation, let the whole mercury run together, and heat it slowly so that the spot of separation is correspondingly moved up, and with it the little air bubble. After that one usually succeeds in separating the mercury again at the desired spot. By suitable heating and cooling it is therefore possible to locate the place of separation so that threads of any length can be separated. In many cases considerable patience must be exercised, and in some thermometers one does not succeed at all. When such threads have been separated, the thermometer is placed horizontally and the threads brought to certain initial positions where their beginnings and ends are read on the scale as accurately as possible. Then they are moved forward and back. An example will show how this procedure is carried out. On a thermometer of 0 to 100° the calibration will be made with threads of, say 20°, on longer scales with threads of 50°, and so on. The observations and consequent calculations are about as follows:

---

[2]) **Mahlke**, Zeitschrift fuer Instrumentenkunde 1893, page 58, 1894, page 34. Buckingham, Bulletin Bureau of Standards, Washington, Vol. 8, page 239, 1912.

Thermometer 0-100°, calibrated with a thread of about 20° length.

Location of ice point $+\,0.4^\circ = p_0$
Location of boiling point $99.7 = -\,0.3^\circ = p_1$

Average location of thread	Correction
0.0 — 20.7	0.7
20.0 — 40.1	0.1
40.0 — 59.8	0.2
60.0 — 80.1	0.1
80.0 — 100.2	0.2

$\frac{p_0 - p_1}{100}$ is designated as correction for the value of a degree. Therefore

$$s = \frac{1}{5}(p_0 - p_1 + \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5)$$

the corrections for the line become

$$s = \frac{1}{5}(+0.4 + 0.3 + 0.7 + 0.1 - 0.2 + 0.1 + 0.2)$$

$$= \frac{1}{5}1.6 = +0.32$$

0	$-p_0$	-0.4
20	$s - p_0 - \delta_1$	$+0.3 - 0.4 - 0.7 = -0.8$
40	$2s - p_0 - \delta_1 - \delta_2$	$+0.6 - 0.4 - 0.7 - 0.1 = -1.0$
60	$3s - p_0 - \delta_1 - \delta_2 - \delta_3$	$+1.0 - 0.4 - 0.7 - 0.1 + 0.2 = 0.0$
80	$4s - p_0 - \delta_1 - \delta_2 - \delta_3 - \delta_4$	$+1.3 - 0.4 - 0.7 - 0.1 + 0.2 - 0.1 = +0.2$
100	p_1	$+0.3$

Control: $p_1 = -5s - p_0 - \delta_1 - \delta_2 - \delta_3 - \delta_4 - \delta_5$
$= +1.6 - 0.4 - 0.7 - 0.1 + 0.2 - 0.1 - 0.2 = +0.3$ as before.

As this can easily be proved it may be omitted here. The application to another length of thread which must always be divisible in 100° is self evident.

But this calculation is not quite complete, as it is a purely linear measurement and does not take into account the variable conditions of temperature and expansion of glass and mercury. Therefore a correction to the above figures must still be applied, which generally depends only on the kind of glass of the thermometer and the mercury, and for which, Scheel (Deutsche Mechaniker Zeitung 1916, page 115) gives a tabulation [3]). A few figures may be given here so that the reader may get an idea as to the values. If a thermometer has standardized ice and boiling points, and moreover is fully of uniform bore calibration, the following corrections are nevertheless still necessary for reduction to the gas-thermometer:

---

[3])Compare also heat-tables of Physikalisch-Technische Reichsanstalt, published by Holborn, Henning and Scheel, 1919.

Glass 59^{III}				Glass 16^{III}				Glass 1565^{III}	
− 30°	−0.13°	+200°	+ 0.84°	− 30°	−0.28°	+200°	+0.29°	0°	+ 0.00°
− 20	−0.07	+250	+ 2.2	− 20	−0.16	+250	+1.1	+ 50	+ 0.05
− 10	−0.03	+300	+ 4.4	− 10	−0.07	+300	+2.7	+100	0.00
0	0	+350	+ 8.0	0	0			+150	+ 0.04
+ 20	+0.04	+400	+12.6	+ 20	+0.09			+200	+ 0.90
+ 40	+0.03	+500	+26.9	+ 40	+0.12			+300	+ 3.9
+ 60	+0.02			+ 60	+0.10			+400	+10.5
+ 80	±0.00			+ 80	+0.06			+500	+23.1
+100	±0.00			+100	0			+600	+44
+150	+0.23			+150	−0.01			+700	+75

A few words may still be said on special types of mercurial and other liquid thermometers. Maximum-thermometers (one form popularly known as fever-thermometer) remain at the highest attained temperature, simply by means of a capillary greatly narrowed at one place. When the temperature increases the mercury passes through this stricture because it is under pressure; when the temperature then drops, the force of cohesion is not strong enough to draw the mercury back and it breaks at this place. To reassemble all the mercury the thermometer is vigorously shaken, bulb outward. Maximum and minimum thermometers often used for meteorological purposes operate quite differently. In such maximum thermometers, the mercury pushes an iron pin before it, which is quite possible as mercury does not moisten iron. This pin remains at the place of highest temperature, and is moved back by impact or by a magnet. In the minimum thermometers, on the contrary, alcohol is used with a glass rod and this stays in it because of surface tension. When the alcohol column recedes with decreasing temperature the glass pin is carried along and it remains in place when the temperature rises again. This pin is made with a melted-in iron core and therefore can be shifted by means of a magnet.

3. Vapor Pressure Thermometers

Thermometers of a special type, which recently have gained extraordinary importance for chemical purposes, are the vapor pressure thermometers originated by Stock and Nielson and developed by them in cooperation with Henning[4]) and others. These, however, are limited in their application in that they cannot be used directly above room temperature. The principle which they utilize is the relation of temperature to the saturation pressures of vapors of pure liquids. Such thermometers can be reproduced very reliably and possess considerable sensitivity. For example the saturation pressure of oxygen in the neighborhood of its normal boiling point changes about 80 mm Hg per degree, while a gas thermometer possesses in the usual form a sensitivity of only 4 mm Hg per degree. The pressure measurement required for the vapor pressure thermometers is therefore often sufficiently exact with the simplest gage. An approved type of such thermometer is diagrammatically shown in Fig. 72. In this form the little glass bulb *a* is connected by a narrow tube with a mercury manometer of about 1 cm^2 section and a length of one meter. In one leg a bulb W of 40 to 50 cm^3 is inserted and the mercury level can be adjusted by an auxiliary container G with rubber hose. As filling material only such substances can be used

---

[4] Stock and Nielson, Chemische Berichte Vol. 39, page 2066, 1906.—Henning and Stock, Zeitschrift fuer Physik Vol. 4, page 226. 1921—Stock, Zeitschrift fuer Elektrochemie Vol. 29, page 354, 1923.—Henning and Heuse, Zeitschrift fuer Physik, Vol. 23, page 105, 1924.

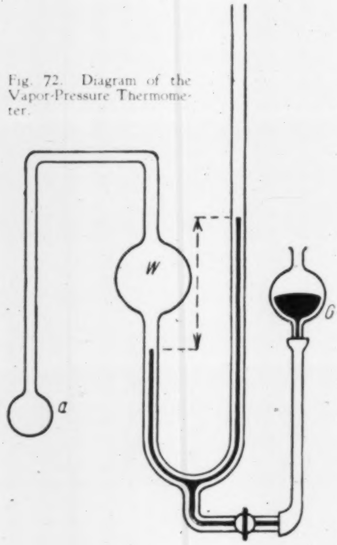


Fig. 72. Diagram of the Vapor-Pressure Thermometer.

which are in the gaseous state at room temperature, and condense in chamber *a* when the latter is exposed to the temperature to be measured. At constant temperature, equilibrium takes place between the liquid there and its saturated vapor the pressure of which is transmitted to the mercury column. As each liquid always distills to places of lowest vapor pressure, the vapor pressure thermometer always indicates only the temperature of its coldest place. This gives the advantage that corrections for emergent thread, etc., are unnecessary. For the same reason these thermometers are not applicable above room temperature if special heating arrangements are not provided. The bulb **W** has the purpose to test the gas filling of the thermometer for presence of harder condensing admixtures. The theory of this thermometer need not be discussed here. It will suffice to tabulate the saturation pressures for a few special cases. It will be seen from the table wherein these thermometers can find an excellent application for the measurement of low temperatures or also, with a filling of a carbon bisulphide for moderate average temperatures.

SATURATION PRESSURE OF VAPOR-THERMOMETRIC SUBSTANCES IN mm Hg.

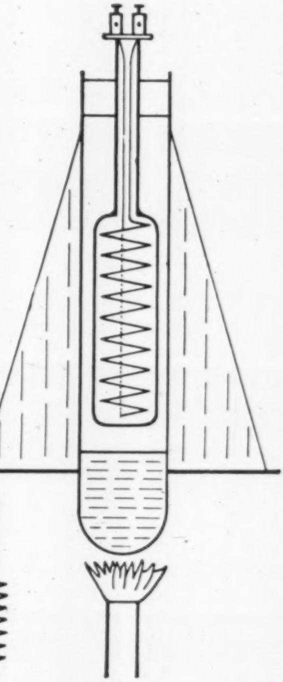
CS_2		SO_2		NH_2		C_2H_4		O_2	
t °C	*p* mm	*t* °C	*p* mm	*t* °C	*p* mm	*t* °C	*p* mm	*t* °C	*p* mm
− 9	82.8	−45	119.6	−75	56.2	−150	14.9	−210	11.5
− 5	100.7	40	162.3	70	82.7	145	26.7	205	33.0
0	127.3	35	217.1	65	117.5	140	45.5	200	80.7
+ 5	159.5	30	285.8	60	164.7	135	74.3	195	174.4
+10	198.1	25	371.3	55	226.8	130	117.0	190	340.7
+15	243.8	20	476.7	50	307.1	125	177.6	185	611.6
+20	297.5	15	605.3	45	409.7	120	260.3	−180	1023
+25	359.8	−10	759.8	40	538.7	115	371.6		
				−35	699.6	110	518.4		
						−105	704.7		

4. RESISTANCE THERMOMETERS

As mentioned above, liquid thermometers can be used only in comparatively narrow limits. Thermometers of medium quality can be made of quartz glass for temperatures up to about 750°C. For glass thermometers these limits are at about 500 to 550°C; and with the special glass 1565^{III} up to 660°C. The other liquid thermometers permit wider limits particularly downward but are far inferior to the mercury thermometer as regards accuracy as they moisten glass. For all other temperatures which cannot be measured with a mercury thermometer without trouble there are needed other measuring devices which will now be discussed.

A very simple type, very excellently applicable for laboratory measurements, is the so-called resistance thermometer based on the principle that the electrical resistance of metallic wires varies with temperature. If, therefore, the exact resistance of a suitable wire is investigated at a few standard temperatures, it can be used as a thermometer in connection with simple resistance measurements which can very easily be made and the manner of which will be discussed later.

The standard material for this purpose is platinum; in some cases pure nickel. Platinum has been investigated especially well. It can be used down to the lowest temperatures and upwards to about 1650°C. For the very lowest temperatures, below —200°C, it fails. Such a resistance thermometer can be made by winding a fine platinum wire (about 0.1 mm) on a suitable insulating support, such as a tube of glass or a sheet of mica. It is also insulated on the exterior by a protective tube or something similar. This so-called resistance element forms one of the legs in a Wheatstone bridge which permits exact resistance measurements with fairly simple devices. It is of importance for this measurement that the current which passes through the platinum coil should remain below a certain value, so that the temperature of the wire should not be increased by it. It can be assumed that in the usual types, 0.01 ampere represents a certain upper limit for the current. If one is in doubt about the correctness of the applied current, the measurement can be made twice—with two currents which have the ratio of 1:2. If R is the resistance at the current 0 and $R_1 = R + x$ the resistance at the current i_1, then the resistance $R_2 = R + 4x$ is obtained with the current i_1, and the resistance R wanted can then be found directly from $R = R_1 - \frac{1}{3}(R_2 - R_1)$.



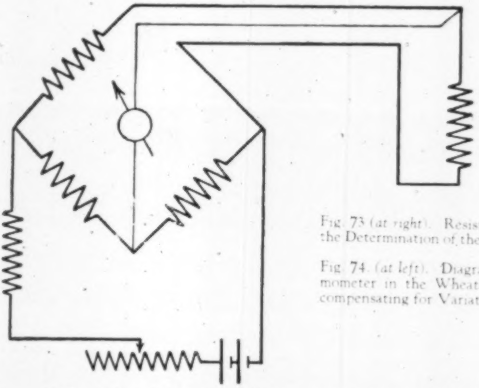


Fig. 73 (*at right*). Resistance Thermometer in an Apparatus for the Determination of the Sulphur Boiling Point.

Fig. 74. (*at left*). Diagram of Connections of a Resistance Thermometer in the Wheatstone Bridge with Leads Arranged for compensating for Variation in Resistance.

It is of importance for the application of resistance thermometers to know the relation of the platinum resistance to temperature. From experimental data this can be represented by a comparatively complex formula,

$$R_t = R_0(1 + at + bt^2) \text{ for temperatures over } 0°.$$

$$R_t = R_0(1 + a_1 t + b_1 t^2 + c_1 t^4) \text{ for temperatures below } 0°.$$

which, for practical purposes, is fairly difficult. The coefficients here, of course, are to be determined experimentally. In practice, this is usually done, if no special weight is laid on greatest accuracy, by measuring the resistance of an element at 0° and 100°. The formula can then be applied.

$$t = \frac{(R_t - R_0)100}{R_{100} - R_0} + \delta\left[\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right]$$

The constant factor δ in the formula can be determined in the simplest way by observing a known higher temperature, such as the boiling point of sulphur.

This boiling point of sulphur, which is of special importance for many thermometric investigations, is determined by an arrangement as sketched in Fig. 73. The sulphur is boiled over a Bunsen burner in a glass tube of about 4 cm diameter and 50 cm length. The tube is protected by a packing of asbestos wool against heat losses at the sides; and by a metal screen against excessive heating by the flame of the burner. In this way a table can be made up for each resistance element, which gives once for all the relation of its resistance to temperature. It is, of course, necessary that the platinum wire be sufficiently aged. In any case, it will be best to procure resistance thermometers ready made from a reliable firm. The measurement of electrical resistance will be discussed in a later chapter.

Only one fact may be pointed out here, namely, the influence of the leads the variable resistance of which must be compensated by a special method. This can be done, for example, by using three leads as shown in Fig. 74. This arrangement of leads eliminates automatically the effects of their variable resistance, which also changes with temperature.

5. THERMOCOUPLES

The second method for measuring high and low temperatures is with the thermocouple which has the further advantage of permitting, with comparatively simple means, a minutely localized measurement of temperatures. It utilizes the well-known physical fact that two metallic wires which are welded together at one end and are exposed at the weld to a temperature differing from the ambient temperature, show a potential difference at their free ends. In practice this is done by soldering or welding two wires of suitable metals at one of their ends and exposing this junction to the temperature to be measured. The two free ends of these wires are kept at a certain standard temperature, such as room temperature, or 0°C by dipping them in melting ice. These free ends are connected to a suitable voltmeter or other arrangement for measuring voltage. The voltage thus measured is directly a measure of the temperature difference between the welded junction and the free ends. The following table gives some information on the metals which can be used for thermocouples and their combinations. It gives, also, the voltages in micro-volts (one millionth of a volt) corresponding to a temperature increase of one degree C. (in the range from 0° to 100°C.).

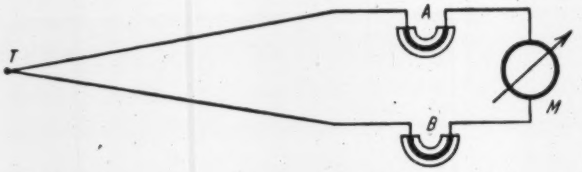


Fig. 75. Diagram of a Thermocouple (T-hot end, A, B-mercury junction at constant temperature and for connection to the milli-voltmeter M).

Pt—Ir	6.5	Microvolts	Ni—Wo	24.3	Microvolts
Pt—Rh	6.4	"	Ni—C	81	"
Pt—90 Pt, 10 Rh	6.4	"	Ni—66 Ni, 34 Fe	22	"
Pt—Ag	7.2	"	Constantan—Ag	41.2	"
Ni—Pt	15.0	"	Constantan—Cu	41.0	"
Ni—Fe	3.1	"	Constantan—Fe	52.0	"

It may, however, be emphasized that these figures represent certain approximations as they depend to a fairly large extent on the purity of the respective metals. It will, therefore, always be necessary to calibrate the thermocouples at suitable fixed points and to base the observations on these values. The most common thermocouple, which has also the widest temperature range, is pure platinum *versus* an alloy of platinum with 10% Rhodium. It can be used without difficulty up to 1000°C. Above this temperature it can also be used, but with certain precautions for it must be taken into account that almost all bodies become conductors at these temperatures, and that platinum is here very strongly attacked by metal vapors. A known formula gives the voltage of such elements as follows:

$$\begin{aligned} e = 2290 &+ 0.89042\ (t-300^\circ) \\ &+ 0.00026875\ (t-300^\circ)^2 \\ &+ 0.00000008073\ (t-300^\circ)^3 \text{ Microvolts.} \end{aligned}$$

This formula only starts at about + 250°C. For industrial purposes another element, of nickel and carbon, is often used in which the insulated nickel wire is placed inside a carbon tube. Besides these, there are especially in use the combinations nickel-iron and nickel-chromium nickel (37 microvolts). For average temperatures the combination copper-constantan or iron-constantan is used, but the use of iron is somewhat risky. In some cases it is quite practical to connect several couples in series. For the measurement of voltage refer to the chapter on electrical measurements. It is best to use the compensation method which is described there but it may be pointed out that special compensation devices have been built for thermoelectric measurements. Otherwise the trade supplies suitable thermocouples together with special galvanometers which permit indicating temperatures directly, as their scales are calibrated in degrees. This arrangement has the advantage that no calculations need be made. As already mentioned, however, all these thermocouples indicate always only the difference of temperature between the welded junction and the free ends. It is therefore necessary to add to the reading the temperature of the free ends, which is not difficult.

6. RADIATION PYROMETERS

Higher temperatures bring difficulties in protecting the valuable thermocouples of platinum and platinum alloys against the action of hot gases, and in general in safeguarding the protecting tubes which become absolutely necessary. For that reason the use of thermocouples is avoided at the highest metallurgical temperatures; and a substitute must be found when the temperature to be measured greatly exceeds 1200°C. The measuring methods discussed so far then are replaced by the measurement of radiation. This cannot be the place for a general treatment of the radiation laws. For that the reader must be referred to handbooks on physics. All methods of measuring radiation are photometrical. That is to say, the brightness of the surface of which the temperature is to be measured, is compared in some manner with a standard source of light, or else an equivalent procedure is employed. From this it is apparent that only the surface temperature can be measured. Another limiting condition restricts the use of radiation measurement, namely that the radiating body is supposed to be in the interior of an entirely closed hollow space, so that "it radiates as a black body" as is expressed in physics. Fortunately, most radiation measurements concern the temperatures of furnaces, so that this condition is almost always fulfilled in practice. Other cases which do not satisfy this condition can be omitted here; such as measuring the temperature of an incandescent filament. Important as such cases are for the physicist, they seldom concern the industrial chemist who generally desires to determine only temperatures of melts in furnaces. Of course, if no great value is placed on the exact actual temperature, the relative temperature can be measured very conveniently. For example, the temperature of a molten metal transported in a pouring ladle is readily determined—though not in degrees on the scale—in order to obtain the proper pouring temperature.

In the following, the most important available constructions of radiation measuring devices will be discussed. Two basically different types can be distinguished, one which determines the total radiation, and that in which partial radiation is received and measured.

An instrument of the first type, utilizing total radiation, is the so-called Féry pyrometer from which the more recent Ardometer of Siemens & Halske has been developed. In the recent type (Fig. 76) a lens focuses the total radiation on the welded junction of a thermocouple *Th* located in a telescope-like tube which can be aimed at the surface to be measured. The thermocouple proper is a so-called vacuum-thermocouple of two 0.03 mm wires of nickel-chromium and constantan, the welded junction of which is covered by a little blackened platinum disc to obtain uniform measuring conditions. This vacuum-thermocouple, at a temperature of 1400°C, develops about 0.015 volt, which is adequate for measuring purposes and permits connecting and indicating on a galvanometer graduated in degrees of temperature. The realization of theoretical conditions in this instrument is not simple, by reason of absorption in lens and glass. It therefore must be calibrated at the factory by means of a black body. It is worth mentioning that the distance of this instrument from the source of radiation does not affect its readings so long as the little receiving plate (platinum disc) of the thermocouple is fully covered by the image of the radiating body. This is easily explained: If the instrument is placed twice as far the disc receives only one quarter of the radiation, but the radiation of an area four times as

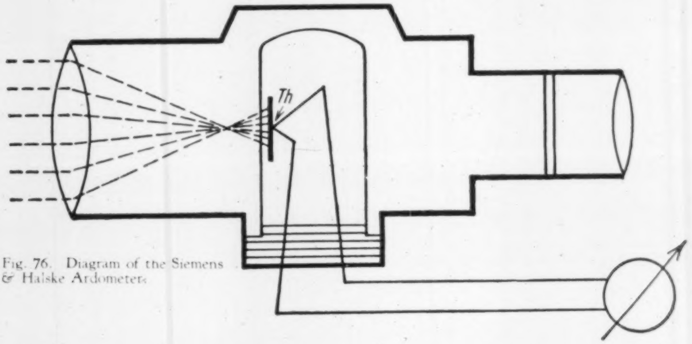


Fig. 76. Diagram of the Siemens & Halske Ardometer.

great is concentrated on it. Therefore, the total energy supplied to the disc remains unchanged. The indications of the instrument are, therefore, independent of its distance from the source of radiation—a fact which holds true also for other pyrometers, and is not without importance when measuring the highest temperatures.

As examples of the other type of radiation pyrometer there may be mentioned the pyrometer of Wanner, and also that of Holborn and Kurlbaum. In the former, a colored glass interposed in the path of the rays only permits the passage of a certain wave length of red light. For comparison, a constant source of light is used consisting of an incandescent lamp which gives a standard illumination to a photometer cube. In the field of vision, one half of the cube is seen illuminated by the incandescent lamp, the other half by the score of radiation. The light of the latter is then diminished by a polarization prism until both halves appear equally bright. The angle of rotation of the polarization device is therefore a function of the observed temperature, and this principle is utilized for graduating a circular scale in degrees of temperature.

Somewhat more common is the second type, in which the intensity of the comparison source of light is changed directly (Fig. 77). In one telescope-like form the instrument is aimed at the surface to be measured and in the field of view the glowing filament of a small incandescent lamp G is seen. This incandescent lamp is connected in series to a rheostat R, a sensitive ammeter S and an electric source E. The current supplied to the incandescent lamp is adjusted so that the glowing filament seems to disappear against the background of the glowing surface observed. This occurs when its brightness, and hence its temperature is the same. The current supplied to the lamp is then a measure of the temperature; and can be read on the ammeter without calculation. This type makes it possible to build the instrument so that very small glowing spots can be observed satisfactorily.

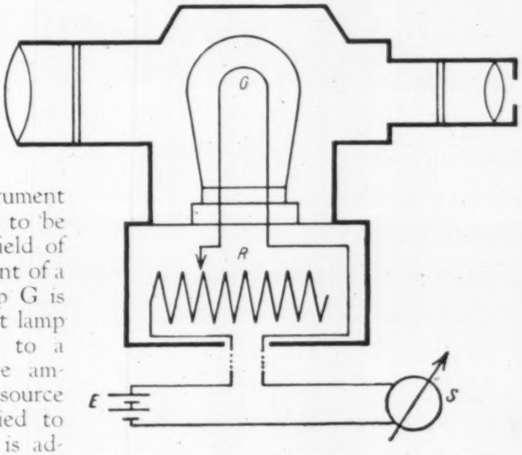


Fig. 77. Diagram of the Holborn and Kurlbaum Optical Pyrometer.

This is not the place to discuss further details of these methods of measuring temperatures, especially as the theoretical principles are extremely difficult to explain briefly. On the other hand the practical handling of the instruments is quite simple, because they all have the advantage that they can be used without error at any distance from the source of radiation and, what is very important, no part of these instruments is directly exposed to the close influence of the radiation. The last named types do not permit a recording as can easily be understood, the former however lend themselves readily to it.

7. Installation of Temperature Measuring Instruments

To conclude this chapter a few general remarks may be made on temperature measurements. It may be pointed out in particular that in order to obtain reliable readings the installation of thermometers, resistance thermometers and thermocouples is of paramount importance. This is especially true when gas temperatures, especially those of flowing gases or vapors, have to be measured. Experience teaches that errors due to incorrect installation can become of such magnitude as to throw off every temperature measurement. In particular, attention must be paid to having the instruments exposed to the temperature to be measured as far as is necessary. Further, it must be taken into account that all measuring apparatus possess a certain inertia, which means that their indications lag behind the actual temperatures. Finally—and this is very important for gas temperature measurement temperature "leaks" must not falsify the measurement. In pipe lines one must always bear in mind that a temperature drop occurs from the centre of the pipe towards the wall. If the thermometer is not placed in close proximity to the center of the pipe it may not even indicate the average temperature of the gas. Moreover, if the heat insulation happens to have been removed for installing it and the protecting well for the thermometer bulb is very thick, the gas near the thermometer will be considerably cooled by conduction to the exterior so that large errors occur; for vapors, even condensation may take place. Finally it must be considered that in many cases, the protection of the thermometers must itself be appropriate so that it will not be destroyed by the surrounding medium. On the other hand this protection must not be too thick because each additional protective thickness, especially of porcelain for the insulation of thermocouples, increases lag to an extraordinary extent. General rules cannot be given for all these cases, but it may suffice to point out these important facts and to emphasize that special care must be exercised. The influence of the emergent thread has been discussed above. Concerning all these details it need only be said that the industrial physical laboratory of the Technische Hochschule in Munich and the Waermestelle in Duesseldorf have furnished extremely valuable data on the installation of temperature measuring apparatus, which will provide elucidation in doubtful cases.

8. Boiling, Melting, and Freezing Points, Change of Boiling and Freezing Points

While temperature measurement constitutes in the majority of cases an auxiliary measurement or a means for carrying out other investigations, it is, in some cases, important in itself for the characterization of materials, specifically when establishing their boiling points or freezing points, and for the determination of their constitution by investigating their boiling or freezing points in solutions. Little more need be said on the methods by which boiling points and freezing points are determined. The procedure offers greater difficulties to the chemist only then, and cannot claim accuracy if as it is the case for quite a number of organic substances, no fixed freezing point exists. Otherwise, the substance to be investigated will generally be placed in a suitable bath together with a sufficiently sensitive thermometer, and the respective point determined by observing the behavior of the thermometer. It is a characteristic of all substances which have a fixed melting or boiling point that the transformation to a new phase consumes a certain quantity of heat which causes the thermometer to remain stationary for a time. The transition from the solid to the liquid state, or from the liquid to the gaseous state, is, therefore, characterized by the fact that the thermometer, if immersed in a sufficiently warm bath together with the substance to be measured, ceases for a while to move uniformly. It is only important that the temperature of the bath be so adjusted that the movement of the thermometer be slow enough. Otherwise the lag of the thermometer may cause noticeable errors.

Considerable difficulties are experienced in determining high melting points. In almost all cases it is necessary to use a thermocouple, which possesses the advantage, incidentally, of being incomparably less sluggish than a glass thermometer. If the substance is melted in a crucible, for example, the instant of melting can be recognized by the indicator remaining stationary. In practice, the furnace temperature is measured simultaneously with a second thermocouple. The method becomes still a little more advantageous if the metal to be tested, in the form of a short piece of wire, is heated by an electric current and the welded junction of the thermocouple connected to it. The current is adjusted slowly so that the piece of wire becomes hotter and hotter, and the instant of melting can easily be recognized by the interruption of the heating current, the thermo-voltage being read at the same moment. It must be taken into account that many metals oxidize when heated and thereby change their melting point. If substances with very high melting points are to be measured, only the radiation pyrometer method can be employed, and the procedure is extremely difficult to carry out considering that the various substances do not radiate strictly as black bodies. It may suffice, therefore, merely to mention this method here, but otherwise recourse must be had to the physical literature.

Before the measurement of freezing points is discussed a few words may be said about the methods by which low temperatures are obtained in the laboratory. As is known, temperatures down to about 20° below zero C can be obtained by a mixture of four parts of chopped ice to one of ordinary salt. Still lower temperatures are obtained by using solid carbon dioxide which is mixed in excess with alcohol. For still lower temperatures the liquified gases must be resorted to, which can be procured comparatively easily. Liquid air gives—193° if it is fresh; nitrogen gradually distilling off and causing the boiling point to rise to—186°C.

A tabulation may also be given here of suitable liquids for heating baths, the first of course water, up to about 100°C, which can be protected against evaporation by a layer of vaseline or paraffine. For higher temperatures various oils are used, such as the two named above, or concentrated solutions of zinc chloride or calcium chloride up to about 140°C. Molten palmin is frequently used up to about 230°C. Molten paraffin can be used up to about 300°. For still higher temperatures, a mixture of equal parts of potassium and sodium hydroxide is taken which is suitable up to 600°C.

The determination of the molecular weight of substances by means of the variation of the characteristic points of their solution is based on the fact that the freezing point of a solution is decreased by the dissolving of a substance in proportion to the molecular concentration of the solution as long as this concentration does not become too high. If, therefore, p grams are dissolved in 1000 g of the solvent, and M is the molecular weight of dissolved substance, the quotient $\frac{p}{M} = \mu$ designates the number of gram molecules or mols dissolved in 1000 g. The reduction of the freezing point is then determined by the equation:

$$\tau = G\mu = G\frac{p}{M}.$$

The unknown factor G is independent of the nature of the dissolved material and depends only on the solvent. This factor can be derived by theoretical considerations or be determined experimentally. For the most important substances it is given in the following table, together with their freezing points.

	t	G		t	G
Ethylenebromide	9.95	11.80	Glacial acetic acid	11.5	3.9
Formic acid	8.6	3.77	Nitrobenzol	5.7	7.07
Benzol	5.6	5.1	Phenol	43	7.20
Bromoform	9	14.40	Water	0.0	1.86

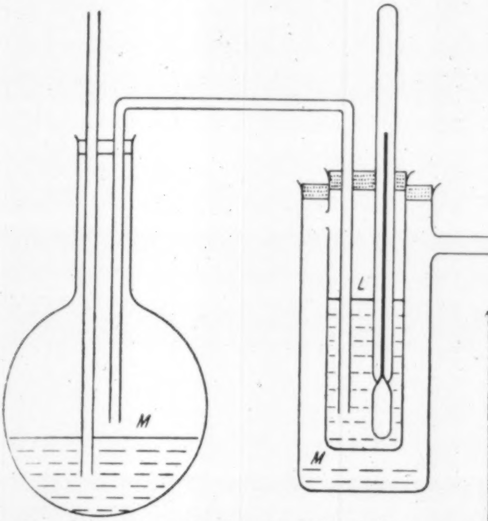
The molecular weight can then simply be calculated from the following formula:

$$M = G\cdot\frac{p}{\tau}.$$

It must, however, be emphasized that this method does not hold for electrolytes, that is for salts, alkalies, and acids because these substances dissociate electrolytically in aqueous solution and, therefore, give an abnormal reduction of the freezing point. The selection of a solvent is therefore fairly limited.

However, the problem is to determine not the freezing point alone but only a difference of freezing points, namely that of the solvent against that of the solution. Both points are determined with the same thermometer, one immediately after the other, and as it is a question of only a few degrees, a Beckmann thermometer is most suitable for use. It remains for both tests without change of position. Still more appropriate, of course, is a differential thermocouple, that is, one with two limbs of the same metal and a connecting third limb of another metal. Such a couple naturally does not develop any voltage if both junctions are at the same temperature, the voltage is developed directly in proportion to the difference of temperatures.

With the usual method of using the Beckmann thermometer, the freezing point of the solvent alone is determined by cooling it quite slowly with continuous stirring and tapping of the thermometer until the temperature has dropped a little below the real freezing point, the solvent therfore being undercooled. If freezing then takes place the thermometer rises a little, remains stationary, and then drops again slowly. This procedure is necessary because the highly sensitive Beckmann thermometer shows irregularities in its indications while the mercury thread drops. This can be caused comparatively easily if the solvent is left to undercool slowly without stirring and then a trace of the frozen solvent is brought into the freezing vessel. The Beckmann arrangement shown in Fig. 78 hardly needs any explanation. It may only be pointed out that the freezing vessel proper is surrounded by an air jacket which makes freezing take place sufficiently slowly and under sufficient temperature equilibrium. The freezing mixture should only be a few degrees below the freezing point as otherwise undercooling occurs too readily. A definite amount of the solvent is put into the cylinder and its freezing point is determined repeatedly. Next, a measured quantity of the substance is put in through the lateral opening and dissolved, and directly afterwards the reduction of the freezing point is determined. In no case should it be more than one to two degrees. It is better to take several weighed quantities of the substances, causing only a few tenths of a degree reduction of the freezing point, and put them in successively. Care must be taken that in repeating the experiment a part of the solvent has not already been frozen out, and that the freezing bath does not remain at too low a temperature below the freezing point of the solution so that a noticeable undercooling takes place. It must be remembered that the large mass of the Beckmann thermometer follows the actual temperature rather sluggishly.



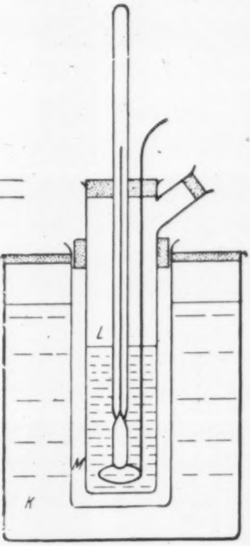


Fig. 78 (*at right*). Apparatus for Measuring the Freezing Point Reduction according to Beckmann. (K–freezing mixture, M–air jacket, L–solution).
Fig. 79 (*above*). Boiling Apparatus according to Landsberger. (M–solvent, L–solution).

About the same as has been said for the reduction of the freezing point holds true for the *increase of the boiling point*. The same formula is applied

$$\tau = S \frac{p}{M},$$

and the constant *S* can be seen in the following table:

	t	*S*		*t*	*S*
Acetone	56.1	1.80	Glacial acetic acid	118	3.07
Ether	34.6	2.11	Methyl-alcohol	64.7	0.93
Alcohol	78.4	1.20	Naphthaline	218	5.80
Anilin	184.3	3.69	Phenol	182	3.60
Benzol	80.2	2.57	Carbonbisulphide	46.2	2.35
Chloroform	61.2	3.88	Water	100	0.52
Diphenyl	255	7.06			

(*t* boiling point)

Otherwise this constant can, as in the case with the reduction of the freezing point, be determined by adding to the solvent weighed quantities of substances of known molecular weight, and observing the *boiling point* *increase.* From the known molecular weight and the measured boiling point increase the constant of the solvent can be calculated.

The process of increase of the boiling point is more difficult inasmuch as boiling, as is known, depends to a considerable extent on the external pressure conditions. Besides, the increases of the boiling point are generally smaller than the reduction of the freezing points. The method of measuring the increase of boiling point by heating the solvent directly in a heating bath cannot be recommended as overheating can take place too readily. In practice one generally proceeds by heating by means of the circulated vapor of the solvent where the vapor at the same time does the stirring. Over-heating is thus precluded. The measuring vessel itself is sufficiently protected by a jacket which the vapor re-enters, and by the condensed vapor. If water vapor at atmospheric pressure is admitted into a solution, for instance, water, equilibrium takes place only when the vapor resulting from the solvent has also reached atmospheric pressure, i.e., when the temperature of the solution has been raised by the water vapor with its temperature of 100° to above 100°. Naturally a certain energy is used up, which is supplied by the condensation heat of the vapor. Part of the vapor is therefore condensed and this dilutes the solution. It follows that the experiment must be conducted differently. It must be stopped immediately after the beginning of the regular boiling of the solution, and—unlike the procedure for reduction of freezing point the concentration of the solution must be determined afterwards by weighing the quantity of the solvent after having weighed the quantity of the substance. The usual arrangement for such experiments according to Landsberger[5]) is shown in Fig. 79.

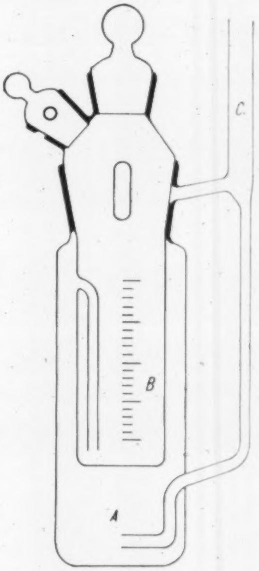


Fig. 80. Apparatus for Measuring the Boiling Point Increase according to Rupp. (A–space for solvent, B–graduated flash for solution, C–cooler.)

Another type is the arrangement according to Rupp[6]) which hardly needs further explanation (Fig. 80).

---

[5] Landsberger, Berichte der Deutschen Chemischem Gesellschaft, Vol. 31, 1898, page 458.
[6] Rupp, Zeitschrift fuer physikalische Chemie, Vol. 53, 1905, page 693.

The Engineer's Handbook of Industrial Instruments

M. F. Béhar*

CHAPTER II

Industrial Temperature Instruments

Part 3—INDICATING PYROMETERS

(*Continued*)

3. High Temperature Measurement Conditions

There is no sharp line of demarkation in industry between those temperatures at which thermoelectric pyrometers may be used and those which call for radiation and optical pyrometers. Temperature is not the only factor in industrial processes—destructive conditions frequently preclude the use of thermocouples even below 2000°F. Fortunately, radiation and optical pyrometers can be used successfully from 950°F and 1100°F, respectively. An interesting thing to remember about radiation and optical pyrometers is that there is no upper limit for their use. Actually, of course, instruments of each of the two classes are made with fairly short ranges in order to make accurate temperature measurements not only possible but convenient. It would obviously be difficult to read closely on a four-inch scale graduated from zero to 3600°F.

The story of the discoveries leading to the laws of radiation and optical pyrometry was briefly told at the beginning of this chapter; and the most important mathematical expressions of the laws given. Now for the practical.

Discussions of radiation and optical pyrometers, in order to be useful to practical men who use them, must be prefaced by definitions of terms that are used in high-temperature work in connection with these instruments. These terms are *a*) radiation, *b*) absorption, *c*) total radiation, *d*) selective radiation and absorption, *e*) the black-body, *f*) emissivity, *g*) monochromatic light. In defining these pyrometric terms an attempt will be made to supply a much-needed explanation in plain English of "what happens and why."

a) *Radiation* is the form of energy which consists of electromagnetic waves traveling at the speed of light, and including X-rays, visible light, Hertzian waves, and others. Their exact nature is unknown. They are called waves because they are studied and measured as if they were beyond doubt transverse waves. And they do act like waves in what is called the ether—that continuous all-pervading frictionless medium which fills all space, between the stars and between the electrons of matter—whose existence is "proved" . . . by the very fact that it transmits radiation! Some of the waves of radiation are shorter than atoms of matter, some are miles long from crest to crest. Outside of these enormous differences in length and frequency they all belong to the same family. They are all the same "thing"—whatever that is. Since all are propagated at the speed of light, their frequency varies inversely with their wave-length, and any ray may be designated either by frequency or by wave-length.

---

*Engineering Editor

In pyrometric work we deal with short waves having frequencies of trillions of kilocycles and therefore instead of designating them by frequency (as in radio work) which would mean writing a lot of zeros, the unit used is the micron, one-thousandth of a millimeter, represented by the Greek letter μ (mu). The other Greek letter, λ (lamda) means simply wave-length. Example, $\lambda = .7$ means the wave-length of 0.7 μ (which particular wave-length is visible to the eye as red light and to a pyrometer as heat).

All surfaces either emit or receive radiations all the time, depending upon what the surface sees. A red-hot rivet held in the open in a pair of tongs sees only colder surfaces and is incessantly radiating. A cold rivet thrown into the furnace sees only hotter surfaces and is incessantly absorbing radiations. That same "cold" rivet put into a refrigerator will radiate heat to the walls of the compartment. Take it out of the refrigerator when it has been chilled, and it will absorb radiant heat from your body and the walls, floor and ceiling. Always and incessantly, heat flows by radiation from hot to cold bodies.

b) *Absorption* means more than merely the exact opposite of radiation. In the case of an "opaque" body it simply means receiving the rays to which it is opaque. No known substance, by the way, is opaque to all wave-lengths of radiation. In the case of a "transparent" body there is no absorption of the wave-lengths to which the body is transparent. No known solid, liquid or gas is transparent to all wave-lengths of radiation. A "translucent" body absorbs part of the radiation to which it is translucent, the quantity of energy absorbed being proportional to its thickness. Carbon dioxide and water vapor are transparent to light rays but merely translucent to longer heat rays and this causes negative errors in the indications of radiation pyrometers.

c) *Total Radiation*—This is an unfortunate term but it has stuck although it certainly is misleading. In pyrometry, "total" radiation does *not* mean *all* the waves in the spectrum of radiation, but in general (1) only those which are generated from hot bodies, and more specifically (2) only those which are capable of heating the colder object on which they fall. The former may include the rays in the spectrum of visible light, from 0.4 μ (violet) to 0.8 μ (red)—which constitutes only one of the 64 octaves in the known spectrum of radiation—and infra-red and ultra-violet rays. There are 9 octaves of infra-red rays, ranging from 0.8 to 400 μ, and 5 octaves of ultra-violet rays ranging from 0.4 μ down to 0.0136 μ. This makes a total of 15 octaves of waves within which are always to be found all of the rays generated from hot bodies—even from the electric arc. As is well-known, the range or *band* of the wave-lengths which are emitted widens with the temperature of the source. A piece of ice when placed in a super-refrigerator cooled by liquid air will radiate heat energy from its surface to the walls of the compartment, but the wave-lengths will be comparatively long—all infra-red and all *feeble*, carrying little *energy*. A heated soldering iron vigorously radiates to any object at room temperature, but only in wave-lengths the shortest of which are still somewhat longer than those of red light. At 1000°F a body starts radiating not only several octaves of infra-red rays but a few of the longest visible red rays. As its temperature rises it emits more powerful infra-red and red rays and starts emitting orange rays. Heat it still more, and in addition to these other rays it emits yellow, then green, then blue and violet rays until its color, to the eye, is white. Above 2700 F it not only emits powerful infra-red and dazzling visible rays, but it starts emitting ultra-violet rays. Thus, the hotter a body becomes, the more energy it radiates, the wider its "broadcast band" and the higher the intensity or energy at *each* wave-length (the familiar E_λ of technical discussions) so that the *total amount of energy* radiated per second per unit area of its surface varies roughly as the *fourth power* of its absolute temperature. In the case of an ideal "black body" (see below) it is the *exact* fourth power. "Total energy" would perhaps have been a better term for scientists to coin at the start. A "total radiation" pyrometer is not affected by X-rays, cosmic rays, radio broadcast waves, or even by the shorter ultra-violet rays actually emitted by an intensely hot body. It is only sensitive to visible or invisible heat rays which it receives *and absorbs*.

d) *Selective Radiation and Absorption*—Everyone is familiar with the fact that various materials, when held in a flame, give off various colors. Most engineers are also familiar with the fact that the spectrum of a source of light is seldom continuous. This applies not only to the visible spectrum but to the ultra-violet and infra-red regions. Highly selective luminous radiation proves an obstacle to the use of optical pyrometers. Note, however, that even with selective radiation, the fourth-power law holds true, for it refers to the total radiation energy—to the quantity of energy and not to its quality. As to selective absorption, this is illustrated by any piece of colored glass; and in pyrometry it must always be remembered that certain gases and vapors absorb not only some of the wave-lengths but some of the corresponding energy of radiation so that both optical and radiation pyrometers are affected in their indications when sighted through thick layers of such gases and vapors.

e) *The Black Body*—This is another unfortunate term. In pyrometry an ideal black body is the *brightest possible* glowing body. Kirchhoff named it the black body because when it is cold it is the blackest possible of all bodies—"receiving all radiation, reflecting none and transmitting none." On the other hand, when it is hot (meaning when it is hotter than any object facing it) it will radiate more heat energy than would any other body at the same temperature. And when it is incandescent, it is the brightest of all bodies at the same temperature. To illustrate: Take a polished hairpin. Dip the curve into a suitable acid until it becomes dead black. Now make it into the filament of an evacuated bulb and pass enough current through it to bring it to white heat. The blackened portion will be two or three times as dazzling as the polished portion. The nearly perfect "black body" is the brightest! You can see the same effect every day in a ladle of molten metal—the clean metal surface radiates less than do the floating impurities, which are much darker when cold. For the same reason, scratches and other cavities are brighter than the smooth surfaces of an incandescent object, as every tool-maker knows.

Not only does a black body radiate *more* energy than any other body at the same temperature, but it radiates it exactly in accordance with the fourth-power law—the total energy per second per unit area varies as the fourth power of the absolute temperature.

No known *surface* acts as a perfect radiator, but 70 years ago Kirchhoff pointed out that a perfect black body can easily be realized, in that any constant temperature enclosure would emit radiation (through a small aperture) to exactly the same extent as would a perfect radiator at the same temperature. This is of extreme importance in pyrometry for the reason that in a uniformly heated, closed furnace, all materials viewed through a small opening appear exactly alike:

Assume a perfect black body, A, and another, B, which is 80% "black." A will radiate an amount of energy equal to what it receives, or 100%. Of the radiations which fall on B, 80% are absorbed, and let us say 15% reflected, while 5% are transmitted through the body as light is transmitted through paper. It follows that B will transfer by radiation all the radiations it absorbs, or 80%; by reflection 15%; and by transmission from the wall of the furnace behind it, 5%; making the "total" radiations per unit area of the surface of B, coming to the opening, exactly equal to those coming from A. That is why the outlines of objects in such a furnace practically disappear when heated to the temperature of the furnace. That is why temperatures may be measured accurately in such a furnace, regardless of the nature of the surface. Which brings us to emissivity.

f) *Emissivity* is simply the extent, expressed as a decimal, to which any surface acts as a black body. For example, lampblack is almost a perfect black body and has an emissivity of nearly 1—so close that a correction factor is unnecessary when using a pyrometer. Iron oxide is very good—0.98. Emissivity corrections must in most other cases be applied when using pyrometers in the open, but only when the actual temperatures are desired. A polished platinum object on the floor of a furnace, sighted through a peephole, will "read" exactly the same as a black body when its temperature is measured by a radiation pyrometer, as explained above, but the moment it is removed from the furnace, before it has time to cool, it will "read colder" on the same radiation pyrometer. Correction factors will be found in the appendix. In all cases where the surface of the material you work with in your plant *varies* in its emissivity, radiation and optical methods of measuring its temperature cannot possibly be highly accurate. There is no help for it. But don't imagine that it is hopeless: An emissivity variation of as much as 8% will mean a variable error of indication never greater than 2% of the absolute temperature. Reason: the fourth-power law.

g) *Monochromatic Light*—This term was briefly referred to at the beginning of this chapter; it will be mentioned again under optical pyrometers. As a matter of fact, it is the explanation of the modern optical pyrometer. Monochromatic means "of one color." Monochromatic light is the light which passes through colored glass.*. In the older optical pyrometers the actual "color" of the glowing object was "measured"—unsuccessfully in most cases, always unsuccessfully above white heat. In all modern optical pyrometers a piece of suitable red glass is used and the *intensity* of that one "color"—that one narrow wave-band of radiation selected from all others emitted by the hot object*—is measured by comparison methods with a high degree of accuracy. Reason: this intensity is a high exponential function of the absolute temperature—the fifth power at maximum.

---

*It is cheerfully admitted that this statement is unscientific. Absolutely monochromatic glass is unobtainable. The best filters transmit a fairly wide band, but with what is called an "effective" wave-length. The determination of the transmission characteristics of each is a long and difficult task, and when it is completed the result is not final. An approximate "constant" must be obtained by plotting several curves and calculating the center of gravity of the final curve for pyrometric use. Then it turns out perhaps that the "constant" *varies* at certain observed tempera

Choice of Radiation or Optical Pyrometers General statements do not apply to all cases because there always are exceptions in every plant, but a few may be ventured:

1. To measure the temperature of hot bodies in the open the optical pyrometer is preferable.

2. Small objects may readily be sighted with optical pyrometers.

3. Radiation pyrometers must be used (a) where continuous indications are desired and (b) where an indicator on a panel board at a distance from the point of application. Recording or controlling instruments can be substituted for the indicator on the panel board, or used in conjunction—just as in thermoelectric pyrometry. In fact, a number of radiation receiving tubes can be installed (on a tunnel kiln, for instance), in a manner similar to thermocouples, and all connected to one multi-point recorder. Fig. 48 shows a permanent installation of a Féry radiation pyrometer.

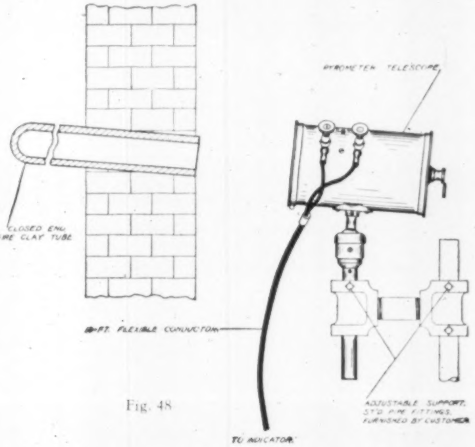

PYROMETER TELESCOPE
CLOSED END FIRE CLAY TUBE
10-FT. FLEXIBLE CONDUCTOR
ADJUSTABLE SUPPORT. ST'D PIPE FITTINGS. FURNISHED BY CUSTOMER
TO INDICATOR

Fig. 48

4. When a man is required to take readings all day long, one after the other, it is less tiresome to tote around a portable radiation outfit which requires only that the tube be pointed, whereas it is a strain on the eye to work with an optical pyrometer all day long. Moreover, the time lag of a radiation pyrometer is much less than the time required for focusing and matching an optical pyrometer.

5. On the other hand, when the vicinity of each point of measurement is uncomfortably hot, some men prefer to use an optical pyrometer which does not require standing as close to the object as does a radiation pyrometer. The working distance of a radiation pyrometer is generally less than 5 feet; with the optical pyrometer, distance does not matter.

6. Statements 4 and 5 must be qualified in view of the fact that some portable radiation pyrometers are of the telescope type.

7. The possibility of error through the human equation must be considered in every individual case. For example, some radiation receiving

---

ture. When corrections are worked out it may next be discovered that the transmission properties of the glass vary with its own actual temperature . . . This is but one of several examples in this chapter, of necessarily broad brief statements. It is believed that unqualified brief explanations and flat statements (provided they are not misleading) serve a better purpose on the whole than would the complete omission of interesting subjects which cannot be presented briefly without sacrificing scientific thoroughness.

tubes must not be held in the middle, because the warmth of the hand will make them read incorrectly.

8. Thick layers of energy-absorbing gases and vapors between the object and the instrument preclude the use of radiation pyrometers.

9. Excessive dust may preclude the use of any fixed tube radiation receiver. Moderate dust requires the use of glass protection, which does not cause errors if kept clean. A correction factor can be used to get the true temperature.

10. For investigations where the actual temperature is desired an optical pyrometer is generally preferable. A high-grade radiation pyrometer can give equally accurate results when the conditions are favorable, with the added advantage of continuous indication and possibility of connecting a recording instrument.

11. For fairly low temperatures the radiation pyrometer is theoretically preferable because its principle makes it applicable even below red heat, but in actual practice, the emf developed by the thermocouple at the focus of a radiation pyrometer measuring a low temperature is so feeble that only the highest grade of instrument should be used for that purpose.

12. As to accuracy, most industrial pyrometers now on the market both radiation and optical—are capable of giving more accurate indications than is generally required. The statements made at the beginning of this chapter, about reliability of indication being preferable in industry to scientifically accurate procedures, are especially applicable here.

4. Radiation Pyrometers

Principle—A radiation pyrometer measures the heat energy emitted per second per unit area from the hot surface at which it is pointed. The principle was made apparent in the definitions above. The actual construction of any radiation pyrometer on the market, however, by means of which the apparently simple principle is employed, furnishes one of the most striking example of the manner in which a number of discoveries may be blended into a most useful instrument. Eight great names are inseparably connected with this device: the sighting telescope recalls Galileo; the concave mirror for bringing the rays to a focus (in this form) takes us back to Newton; the thermal junction was the discovery of Seebeck; the moving-coil galvanometer originated with d'Arsonval; and the fourth-power temperature scale enshrines the names of Kirchhoff, Tyndall, Stefan and Boltzmann. In all justice, we should add as a ninth name that of Féry, who so ingeniously combined the work of his predecessors.

Essential Parts

1. A *collecting system* whereby a beam or cone of radiation is focussed on the sensitive element. This collecting device may comprise (a), lenses, (b), a mirror, (c), a combination of a and b, (d), a tube-and-cone arrangement. Some instruments must be focused by hand, others are of the fixed focus type.

2. A *sensitive element* which may be either (a) a tiny bimetallic spiral thermometer or (b) a thermocouple. In the latter case, the thermocouple junction is in back of a blackened disk.

3. *An indicating system.* In the case of the bimetallic coil receiver, this is a direct connected pointer traversing a scale. In the case of thermocouple radiation receivers, the indicating system is essentially like that which is employed for an immersion thermoelectric pyrometer.

4. *A means of cutting down radiant flux* to provide more than one range. Generally a set of diaphragms or "windows." The use of a smaller window usually means cutting down the "cone of vision" and increasing the "distance factor." (See below.)

The indications of all such instruments are basically independent of the distance from the radiating body, provided that the former be large enough. It is simply necessary to limit the beam received at the pyrometer to a cone of constant apex angle. Then, provided that the base of this cone, or "circle of application," is completely filled, the reading will be independent of the distance. For as the energy decreases with the square of the distance, the rays from the radiating body included in the cone increase in the same amount, so that the energy falling on the receiving system remains constant.

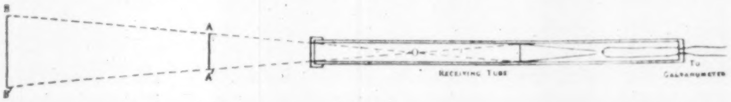


Fig. 49

This is evident from the diagram (Fig. 49) of a Thwing portable type radiation receiving tube. Since the containing tube is dead black, no radiations reach the conical mirror from any part of the observed surface outside the solid angle AOA', and all radiations from the surface falling within this angle are transmitted by multiple reflection to the thermocouple at the small end of the cone. If, for instance, the energy E, received from a surface of area S at a distance OA be compared with the energy, E', received from the larger portion of the same surface S' subtended when the distance is $OB = 2OA$ it will be seen that:

$$\frac{E}{E'} = \frac{S}{OA^2} \div \frac{4S}{2OA^2} \text{ or, } E = E'$$

since the area increases with the square of the distance and the intensity varies inversely with the square of the distance. Note again, however, that while the distance BB' may be varied, the hot object must always have sufficient area to fill the circular surface of which BB' is the diameter.

The diameter of this surface, with the Thwing instrument, should be 1 inch for every 8 inches of distance from the end of the tube for a low range (2500° F.) instrument and may be correspondingly smaller for instruments of higher range which have smaller diaphragms or windows.

In practice one may be sure that the safe distance is not being exceeded as long as increasing the distance does not decrease the reading. (Due to optical imperfections the indications of most instruments actually deviate somewhat with the distance.)

Industrial Forms

Féry Pyrometer—The first pyrometer on these lines was devised by Féry in 1902. It consisted of a telescope, the object-glass of which focussed the rays from the hot source on a tiny thermocouple connected to a delicate galvanometer, which by its deflections measured the relative quantities of energy falling on the junction under varying conditions. By taking one accurate reading of a furnace held at a known temperature, the whole scale of the galvanometer could be divided to read in temperatures directly, by virtue of the fourth-power law. One objection to this form of the Féry pyrometer was that it did not strictly apply the radiation law, because a large proportion of the radiant flux from the heated source cannot pass through glass. In 1904, Féry met this objection by using a concave mirror to focus the radiations on the junction. This form of the Féry pyrometer is used at present. (Fig. 50.) It is manufactured in the U. S. by the Taylor Instrument Companies and in England by the Cambridge Instrument Co. which first brought it out. An interesting feature is the method of focusing by means of a small split mirror. The image of the object sighted is viewed through an eyepiece at the rear. It is in two halves which are out of alignment until the main collecting system is focussed on the receiving disk—which is done manually by a rack and pinion.

Taylor Instrument Companies—A concave mirror ("reflecting lens") concentrates the radiant flux on a receiving disk of copper $\frac{1}{16}''$ in diameter and .003″ in thickness located at the thermocouple junction. One thermocouple is used, made up in the form of a plus mark or cross with a receiving disk placed at the intersection of the thermocouple elements. The thermocouple material is iron-constantan ribbon. The available ranges are 1000 to 2400°F, 1500 to 3600°F; 500 to 1300°C, 900 to 2000°C. The focus of the reflecting mirror is adjustable. The distance the telescope must be placed from the furnace is determined by the size of the object. An object 3″ in diameter can be read at a distance of 10 feet from the furnace. This gives a *distance factor* of 1 to 40 (which expression will be used henceforth). The time lag to attain full scale reading with each range is 3 to 5 seconds. Approximately 6 millivolts are developed at top mark of each range. With the diaphragm open at 2400°F, or with the diaphragm closed at 3600°F, the temperature of the receiving disk at the thermocouple is approximately 210°F.

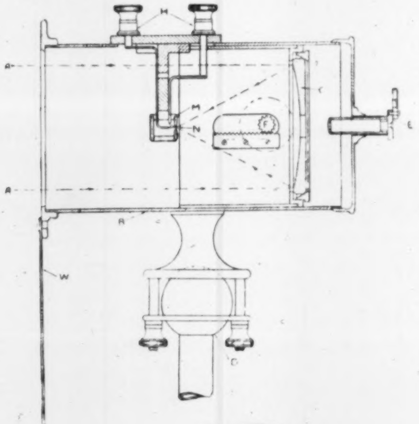


Fig. 50 (*Left*). Cross-section of Fery Optical Pyrometer. AA—Beam with large diaphragm. C—Collecting mirror. E—Ocular for focussing image on disk. F—Focussing rack. M—Split mirror which shows image out of line when main collecting mirror is not properly focussed. N—Receiving disk at hot junction. (*Cambridge Instrument Company.*)

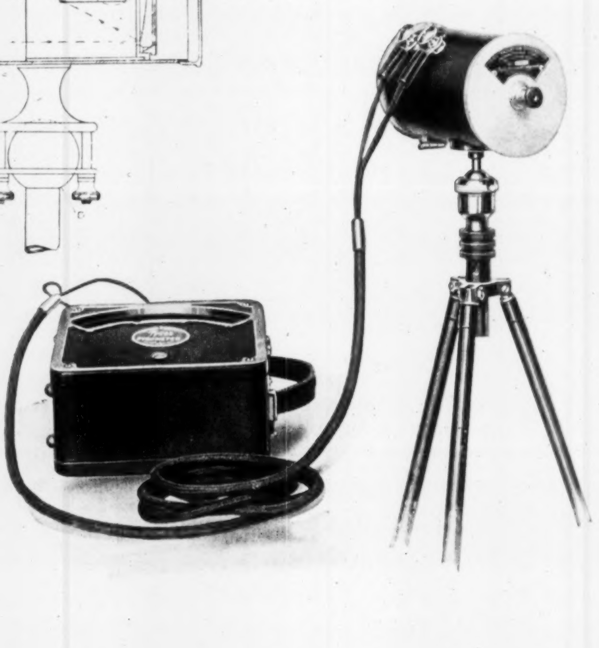


Fig. 51

Fig. 51 shows the American Féry pyrometer. The indicating instrument, as may be seen, is of the vertical coil type with a long scale—approximately $6\frac{5}{8}''$. An accuracy of 1% of the scale is guaranteed.

Cambridge Instrument Co.—The Féry radiation pyrometer made by this firm is similar in its design. Some of the differences are that the collecting mirror is made of stainless steel; that two thermocouples are used, made of "special" thermo-elements which develop from 4 to 12 millivolts at the high point of the scale, depending upon the range, and that the distance factor is 1 to 24. A cross-sectional view is shown in Fig. 50.

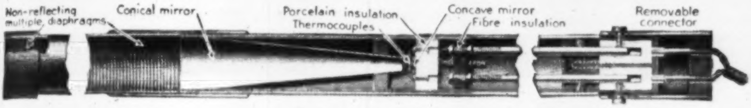


Fig. 52

Thwing Radiation Receiver—The construction of this device is shown in Figs. 52 It is of the universal or "fixed" focus type. The radiation passes through a series of non-reflecting diaphragms and falls on a conical mirror which reflects the rays back and forth until they finally are concentrated on a thermocouple. It is built in two types—portable and stationary. The latter is made with a ventilated series of diaphragms between the receiving tube and the furnace. Six thermocouples are used, connected in series. The distance factor is 1 to 8. The time lag to attain full scale reading is 15 seconds, and 7 to 10 millivolts are developed at the high point of each range. The hot junction temperature is about 210°F when the measured temperature is 3000°F. The portable type must be held at the end; if grasped in the middle, a slight error is introduced.

Leeds & Northrup Receiver—This, too, is a fixed focus receiver of the thermoelectric type. Fig. 53 shows a typical industrial installation. The tube is light and can be held by hand when the object sighted is sufficiently large. The distance factor is 1 to 10 for all standard receiving tubes except that to 1800°C in which case it is 1 to 12. The radiant flux is concentrated on a thermocouple by a convex mirror at the end of the tube farthest away from the furnace. In this, this type of receiver resembles the Féry, but an important difference is that instead of focussing an image of the hot body on the sensitive element, the sighting window or diaphragm (at the end of the tube nearest the object sighted) is itself accurately focussed. This particular fixed-focus principle is known as the focussing of the "heat image" and can readily be understood by thinking of what you see when you hold, between your eye and a furnace opening, a large sheet of cardboard in which a hole has been cut. The intensity of the heat image which you see—*through* the hole but apparently *at* the hole—is independent of your distance from the furnace. What is true for the eye is also true for any portion of the mirror. Therefore, it is true for the entire mirror. The mirror is mounted in a cell and sealed in the correct position, to prevent tampering. Users having technical skill, however, may break the seal, remove the mirror cell, clean it and replace it. To meet industrial conditions where entry of dust cannot be avoided and to delay the necessity for cleaning the concave mirror itself, a separable protection window is fitted at the center of the receiving tube, which is jointed at that point to allow of easy cleaning of the window. The emf developed by the thermocouple when sighting an object at 1400°C is said to be higher than 14 millivolts.

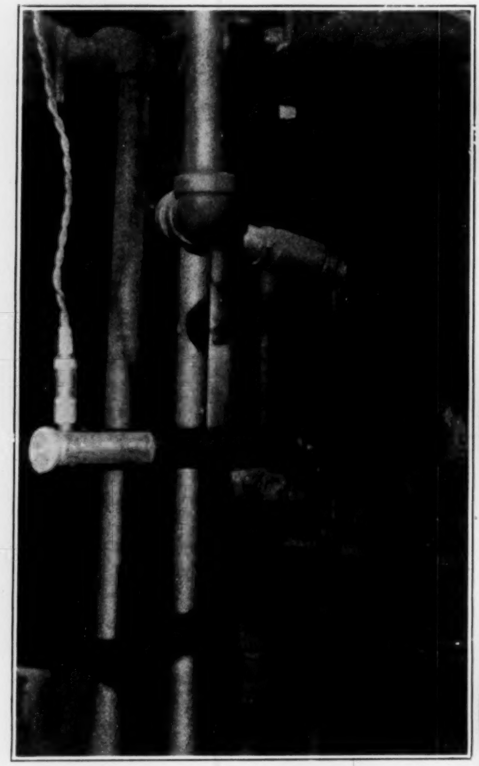


Fig. 53. Fixed radiation receiver (*Leeds & Northrup Co.*).

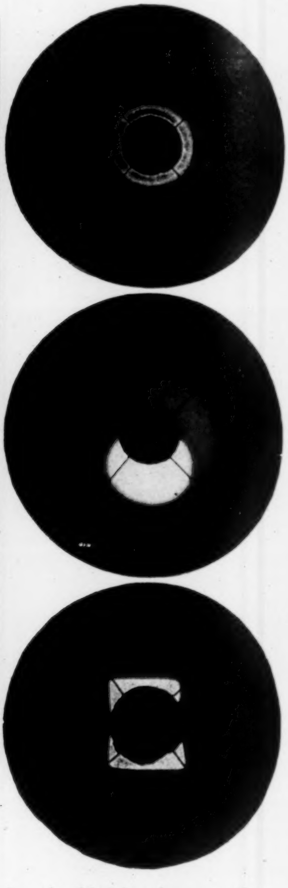


Fig. 54. Correct (*top*) and incorrect sighting of Ardometer. (*Bacharach Industrial Instrument Co.*)

Foster Receiver—Exactly the same as the Leeds & Northrup. (It is the English-made L & N, or the L & N is the American-made Foster.)

The Ardometer—Manufactured by Siemens & Halske and distributed in the U. S. by the Bacharach Industrial Instrument Co. Its construction is very roughly shown in Fig. 55. It embodies a telescope with an objective lens D and an ocular lens E. The radiation from the hot body A is focussed by the object lens on to a blackened platinum disk to which two pairs of very thin thermocouple wires are hard-soldered. The ends of the thermocouple wires are connected to a portable galvanometer, on which the temperature is read off. Panel board indicators and recorders are also furnished. With Ardometers which are intended to measure temperatures up to 1200°C (about 2190°F) the thermocouple is fitted inside a vacuum bulb. To insure more rapid

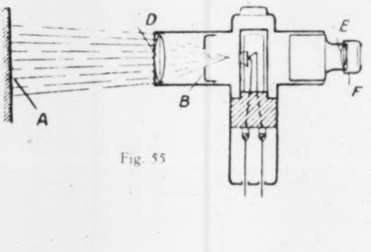


Fig. 55

equalization of temperature, the bulb is surrounded by a metal casing which is provided with two holes in the neighborhood of the receiving disk, for the rays to pass through. In Ardometers for high temperatures, thermocouple bulbs filled with argon are employed. The diaphragm B determines the particular temperature range of the vacuum or of the argon bulb instrument.

The object lens is sighted on the glowing surface. The observer then looks through the small ocular lens, after he has suitably adjusted it to his own eye, in order to enable him to see sharply the object to be measured. He also sees, in the center of the field of vision, the platinum receiving disk. The telescope is directed in such a manner that the brightest part of the surface of the hot body, or that part the temperature of which is required, is just covered by the platinum disk. The observer should now see a uniformly bright zone all around the circumference of the disk. Fig. 54 shows actual photographs of correct (top) and incorrect (middle) sighting of a small round object such as a furnace peephole, and an example (bottom) in which the hot body is insufficiently large as viewed, in which case the observer should come a little closer. These "educational" photos apply to various other makes of the direct-vision or telescope type of radiation pyrometer.

In order to avoid dazzling the eye during adjustment, a small colored glass may be inserted in front of the ocular lens. The diameter of the receiving surface for temperatures up to 1600°C (about 2910°F) is 3 mm. (1/8″), and for higher temperatures 2 mm. (1/13″). The distance factor for ranges up to 3000°F is 1 to 17; for higher ranges 1 to 23. The time lag is remarkably short: only 3 seconds for full deflection. The accuracy is well within 1% even when the temperature of the receiver varies.

"*Pyro*" (Pyrometer Instrument Co.)—This is a self-contained collecting lens type instrument of German make (Dr. R. Hase) and is shown in figures 56 and 57. One thermocouple is used, and is located in an evacuated bulb, this arrangement being similar to that of the Ardometer. The distance factor is 1 to 15. The time lag is said to be about 4 seconds; 80 to 100 millivolts are developed, depending upon the range when the temperature of the receiving disk is around 200°F. It is said that temperature fluctuations around the receiver do not affect the indications. The construction of the instrument is interesting in that the galvanometer is built around the telescope so that no leads are necessary. It would seem that it takes a little practice to use this instrument properly. A feature of convenience is the button ("clamping stud" on diagram) which is pressed when the instrument has been sighted, and then released. The pointer remains fixed until again released by a second pressure of the button. The slogan, "Aim at the furnace, press the button and release," has popularized this instrument in the U. S. and such popularization has helped to acquaint plant men with both radiation and optical pyrometers.

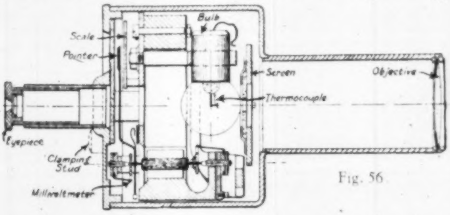


Fig. 56

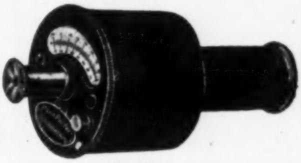


Fig. 57

"*K. & S*" (Colonial Supply Co., U. S. Agent of Keiser & Schmidt)—The sensitive element is not a thermocouple but a bimetallic spiral about $^1/_{10}''$ in diameter and 1/1000″ thick, placed at the focus of a collecting lens $1\,^1/_8''$ in diameter with a 2″ focal lengths. (Fig. 58.) That prolific French physicist, Féry, is credited with the invention of this type of instrument. This particular instrument is a simple and compact device—almost a pocket instrument. The method of compensation for variation of room temperature is ingenuous: The scale over which the pointer travels is automatically shifted by a compensating spiral. This scale is transparent and can be seen at the same time the glowing surface is viewed through the ocular, enlarged about 8 times. The distance factor is approximately 1 to 12. The entire instrument is self-contained, is 6″ long and 2″ in diameter, and weighs 6 ounces. The time lag is said to be about 10 seconds.

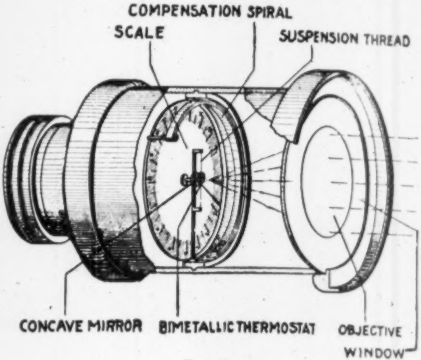

COMPENSATION SPIRAL
SCALE
SUSPENSION THREAD
CONCAVE MIRROR
BIMETALLIC THERMOSTAT
OBJECTIVE WINDOW

Fig. 58

"*Pyrradio*" (Hartman & Braun)—An interesting feature of this German instrument (Fig. 59) is the automatic compensation for variations in room temperature, consisting of a crescent shaped diaphragm controlled by a bimetallic strip between the lens L_1 and the thermocouple receiving junction disk P. This is said to compensate both for receiving disk temperature and cold junction temperature. The distance factors are 1 to 14 for an instrument made up for ranges up to 1200°C, and 1 to 20 for instruments designed for higher temperatures. Above 1400°C the thermocouple develops more than 30 millivolts, so that vertical coil indicators are only required for the low range instrument.

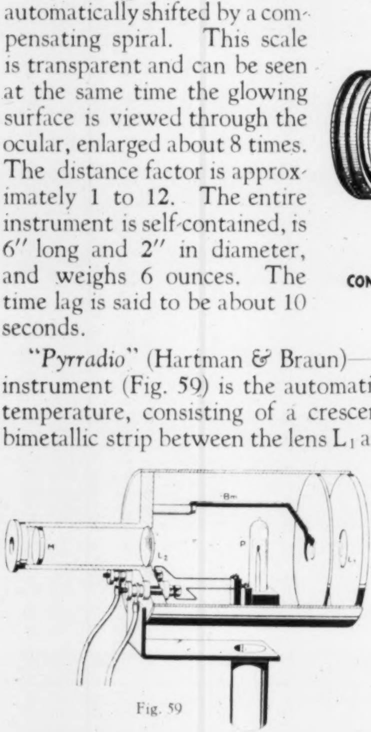


Fig. 59

"*Mikrotherm*" (Paul Braun)—Another German instrument, in which the radiation is focussed by a lens on the junctions of ten tiny iron-constantan thermocouples (see rough sketch, Fig. 60). The receiving disk is made up of ten superposed individual disks, each welded to a junction, and this assembly is not contained in a bulb. The distance factor is 1 to 20. This instrument is recommended for fixed installation—probably, we suspect, because the time lag is 60 seconds. For the range 500-1200°C the emf is 21.14 millivolts on the average, according to a series of tests made for this Handbook. For the range 900-1800°C it is 92.5 millivolts. Intermediate ranges,

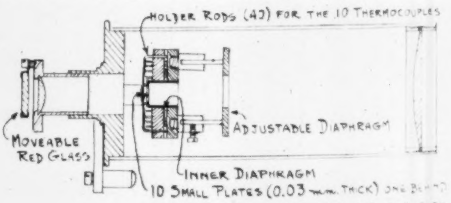

HOLDER RODS (AJ) FOR THE 10 THERMOCOUPLES
ADJUSTABLE DIAPHRAGM
MOVEABLE RED GLASS
INNER DIAPHRAGM
10 SMALL PLATES (0.03 mm. THICK) ONE BEHIND THE OTHER AND INSULATED FROM ONE ANOTHER BY MICA

Fig. 60

intermediate emf's. Temperature fluctuations around the receiver had no appreciable effect on the accuracy of indication.

P. J. Kipp & Zonen—This Dutch firm manufactures two models of a radiation receiver which has no fewer than 18 thermocouples in series, the elements being constantan versus manganin. The time lag is remarkably short—only 2 seconds for the thermopile to attain its final temperature and 3.7 seconds for the full deflection of the millivoltmeter. The construction of this instrument would seem to make it suitable for the laboratory rather than for plant service.

Whipple-Fery Closed Tube Pyrometer—This is a modified form of the Féry radiation pyrometer and is suitable for measuring high temperatures in some cases where other forms of radiation pyrometers would be unsuitable, e. g., in salt bath furnaces, in open crucibles of molten metal, etc. By the use of this instrument the actual temperature of molten metal in a crucible or ladle can be obtained regardless of the condition of its surface. The pyrometer consists of a long iron tube, closed at one end by a blind tube of fire-clay, carborundum, quartz or steel (to suit various requirements). This tube is the portion subjected to the temperature to be measured. The radiant flux from the closed end is reflected at the opposite end of the instrument assembly by the concave mirror, and brought to a focus at which is fixed a small thermocouple. A wide flange is employed to protect the hand of the observer from the heat in the case of open crucibles. It is always essential to have a non-porous tube, since the presence of any fumes in the interior would seriously cut down the radiation to the sensitive element.

"*Iscometer*" (W. H. Joens & Co., Germany)—This is a receiver connected by means of a suitable long metal tube to a closed-end refractory tube—the three parts being in line. The refractory tube can be immersed in molten metals as well as installed through a furnace wall. The sensitive element is a thermocouple which develops 75 millivolts at top mark of scale range.

Calibration of Radiation Pyrometers—This is a very easy matter. The received is pointed at a nearly perfect black body, which is either found in some furnace where the conditions are suitable, or can be made up by winding an electric heating coil around a porcelain tube closed at one end, as described in various scientific publications. The essential requirement is that the temperature of the black body be accurately measued by means of a good standard pyrometer. As with all other industrial instruments, the important thing on the large majority of applications is not so much to measure the *true* temperature as to be able to reproduce temperature conditions day after day. Therefore, check up your radiation pyrometers fairly frequently—not to make sure that they measure the exact temperature, but simply to make sure that they have not "gone bad." The radiation receivers, the electrical instruments used in connection with them, and the self-contained industrial radiation pyrometers, while not entirely fool-proof, should "stay put" in their indications for months—and sometimes for years of service. *Above all, keep the collecting lenses and mirrors clean!*

5. Optical Pyrometers

A scientific explanation of the optical pyrometer cannot be given here in full. It is necessarily long and involves a minimum of one page of mathematical expressions in addition to the straight text. The following practical explanation is made as brief as consistent with adequacy.

1. A black body emits a continuous spectrum at all temperatures.

2. The energy curve of this spectrum is a hill with two slopes; toward the ends of the spectrum the rays emitted are very feeble, so feeble that they are seldom investigated.

3. The crest of the hill is not in the center of the spectrum but always over to the left: most of the energy is carried by short waves. The left slope of the hill is sharp, the right slope gentle—so gentle that although the spectrum may extend to waves longer than 50μ, investigations seldom extend beyond 20μ and sets of curves published in works on optical pyrometry generally stop at 6μ.

4. As the temperature rises, three things happen, all according to definite laws:

First. The hill rises. The area of its cross-section (total energy) increases as the fourth power of the absolute temperature. (Stefan-Boltzmann Law.)

Second. The crest of the hill shifts further to the left. *More* of the energy is carried in *shorter* waves. (Wien's Distribution Law.) At the same time the spectrum widens at the left because the body starts emitting shorter waves. "Dull red" is the temperature at which the left end begins to extend into the octave of visible rays.

Third. Not only does the hilltop advance closer and closer to the left end of the spectrum but the height of this hilltop above the zero base line varies exactly as the *fifth* power of the absolute temperature.

5. Thus for any temperature we know the *area* of the curve (E_T), the highest point (E_{max}) and the exact location of this peak (λ_{max}).

6. In fact we know the *shape* of the energy distribution curve corresponding to any temperature.

7. This being so we can select any convenient wave length in the *visible* part of the radiation spectrum, and the intensity of the *light*, which we can actually see with our eye at this visible wave length, will be an exact indication of the temperature. The hilltop itself need *not* be selected. Any point on the visible left slope of the hill will do.

That is the reason why we can *measure* temperature accurately, according to definite laws, by measuring the intensity of one convenient visible narrow wave-band—known as "monochromatic light."

Methods

This intensity is measured with the eye, by any convenient method. Among these methods (which determine the "type" of optical pyrometer) are the following:

1. The absolute method, in which a wedge of very dark glass is moved between the eye and the object sighted, until the light is completely absorbed, so that the glowing object can no longer be seen. A scale is provided whereby the vanishing point temperature can be read directly. This is the principle of the Wedge pyrometer.

Comparison methods are preferable to the foregoing because the use which was made of the eye just previous to the time of using the pyrometer does not matter as much. In all comparison methods an essential is a "comparison source." The measurement is then made by matching the comparison source with the object sighted. The following are all comparison methods:

2. A telescope with a divided field. The eye sees one-half of the field as a surface evenly illuminated by the glowing object and the other half illuminated by the comparison source. This sounds simple, but the original industrial example was the Wanner pyrometer which embodied a complicated optical system comprising two compound collimating lenses, a direct vision spectroscope, a Wollaston prism, a biprism, a nicol prism and other absolutely essential parts. It is no longer made but the rotating prism principle is still used in practical industrial optical pyrometers.

3. A telescope through which the glowing object itself is viewed and which contains a glowing filament which is viewed at the same time (see Fig. 63). The match is made by varying the current passing through the filament. This principle is used in several pyrometers described below.

4. Same as 3, but the match is made by a wedge of dark glass, the filament operating at a definite standard brightness. This principle is used in the F & F Pyrometer.

5. Instead of a "geometrical" or actual wedge as in 4, a "photographic wedge" the gradual "thickness" of which is produced by the graduated shade of a photographic emulsion on glass of constant thickness. Used in the "Pyro."

Industrial Forms

The usual classification into "optical" (split field) and "disappearing filament" can well be dropped. All are optical since the human eye must be used. The logical division is into "absolute" and "comparison" as set forth above. The latter, being more important, come first.

Comparison Types

Leeds & Northrup—Disappearing filament type, variable filament temperature sub-type, developed under the fundamental Morse (American) patents. Fig. 62 shows the construction. The radiation from the body whose temperature is to be measured is brought to a focus at the point F by the object lens L. A tungsten lamp filament is placed in the plane of the image produced by the lens. This filament receives current from a small battery enclosed in a portable case with a rheostat and a milliammeter. The incandescent filament and the image are observed through the eyepiece.

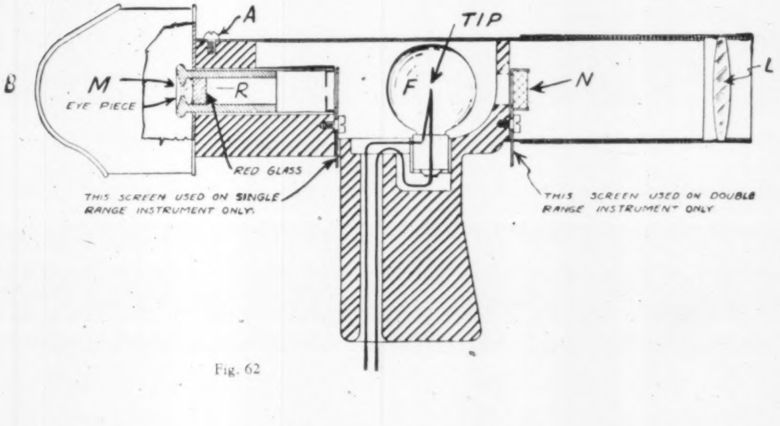

A
TIP
B
M
EYE PIECE
R
F
N
L
RED GLASS
THIS SCREEN USED ON SINGLE RANGE INSTRUMENT ONLY.
THIS SCREEN USED ON DOUBLE RANGE INSTRUMENT ONLY

Fig. 62

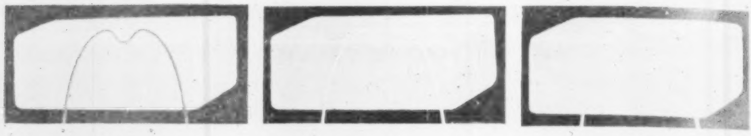


FIG. 63. CORRECT AND INCORRECT FILAMENT AND OBJECT LUMINOSITY, AND WHAT TO DO, DEPENDING ON TYPE OF PYROMETER. (*Leeds & Northrup Company.*)

Filament shows too dark. Increase current by means of rheostat, or rotate wedge to make object appear less bright.

Filament shows too bright. Decrease current, or rotate wedge to make object appear brighter.

Intensities correctly matched. Filament cannot be distinguished against background of object. Read the temperature.

By means of the rheostat the lamp current is adjusted until the brightness of the filament is just equal to that of the object. Three illustrations of the filament (Fig. 63), as seen through the telescope, make clear the method of adjustment. The accuracy of the method is apparent when it is understood that the effect of radiation upon the eye varies some 14 times faster than does the temperature at 3400°F—20 times faster at 1600°F. A piece of red glass, set in the eyepiece at R, furnishes "monochromatic" light which is necessary as explained above. The screen N, made of a suitable dark glass, is used for the measurement of temperatures above 2500°F, up to the highest known temperatures. A different calibration is used with the absorbing screen (because the effective wave-length is altered) but the range without the screen and that with the screen overlap by several hundred degrees. This makes it possible to check the accuracy of the 2 scales by observing a hot body within the overlapping portion.

Holborn-Kurlbaum (Siemens & Halske—U. S. Distributors, Bacharach Industrial Instrument Co.)—Exactly the same in principle as the Leeds & Northrup. The hairpin filament, the telescope and eyepiece, are said to have originated with Holborn & Kurlbaum.

"*Pyro*" (Pyrometer Instrument Co.)—This is a self-contained instrument of German make (Dr. R. Hase) and is illustrated in Fig. 64 which should be self-explanatory to one who has read the explanations above. An advantage is light weight, the entire instrument weighing 3 pounds. The match is made by means of a circular "optical wedge" of glass on which an emulsion of varying density is deposited. The purpose of the ammeter, is to standardize the current passing through the filament and with it the intensity of the filament light. The small electric bulb, may be removed and a "master" bulb inserted for checking the former periodically. The master lamp is made with a red tip to distinguish it. Current is supplied by a standard flashlight battery (Ever-Ready 703—4½ volts, or similar). The lamp requires approximately 60 m. a. so that battery renewals are necessary at fairly long intervals.

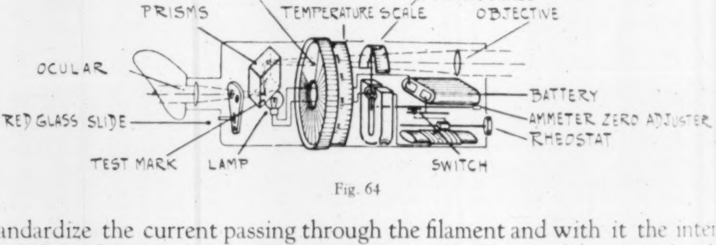


Fig. 64

"*Pyropto*" (Hartmann & Braun)—This German instrument is exactly similar in principle to the L & N or Siemens & Halske. It is self-contained like the Pyro but is shaped like a T, the batteries being contained in the vertical part.

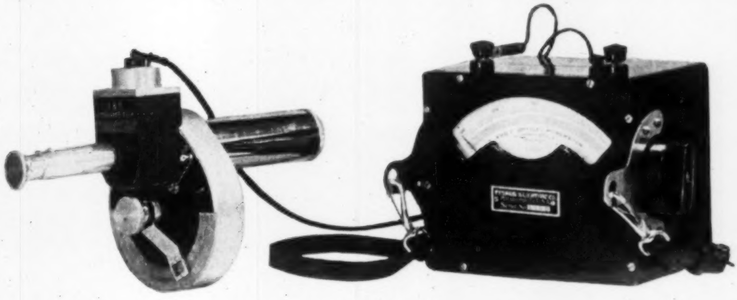


Fig. 65

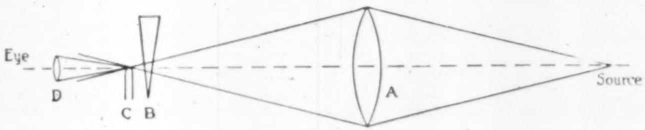


Fig. 66

"*F & F*" (Fisher Scientific Co.)—This instrument (Fig. 65) is of the true "geometric wedge" type, in which the comparison standard is a hairpin filament maintained at standard intensity. Fig. 66 shows diagramatically the optical system of this pyrometer. It consists of a telescope with objective lens A and ocular lens D. A special lamp C with a hairpin filament is mounted on the focal plane of the objective and the tip of the filament is viewed through the ocular lens. The observer thus sees the filament superposed on the well-defined image of the object sighted. The filament operates at a definite brightness obtained by setting the current through the lamp to a standard value. At B is mounted an adjustable wedge of black absorbing glass. By varying the position of this wedge, a thicker or thinner portion is brought into the line of sight and the brightness of the image of the source viewed, may be set to a photometric match with the tip of the filament. In the actual instrument the wedge is not linear but semi-circular as in the Pyro instrument. The F & F wedge, however, is solid or geometric, the graduated density being produced by a variable thickness of dark glass. The absorbing glass is cemented to a similar semi-circular wedge of clear optical glass of the same refractive index. The combination is accordingly a disk of a uniform thickness but one in which the thickness of black glass varies in a definite manner with the orientation. The pointer which indicates the temperature is directly connected to the wedge mounting. The standard range is from 1600 to 4000°F. This instrument was developed in America by the makers.

Fig. 67

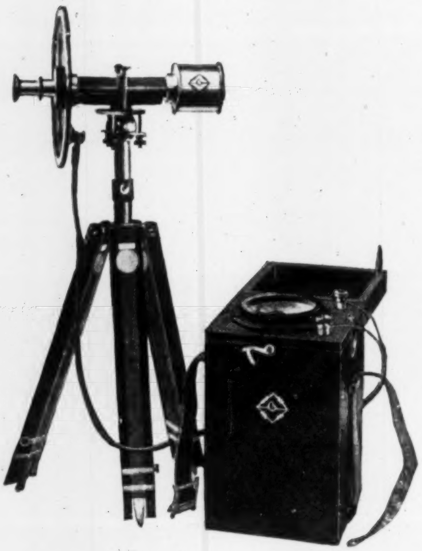
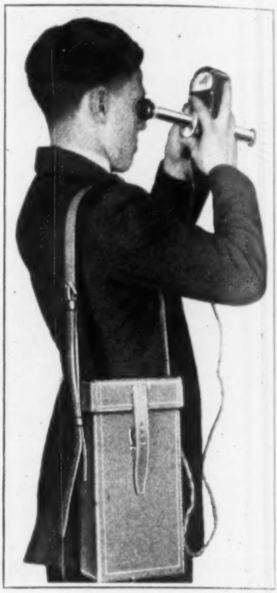


Fig. 68



Cambridge Optical Pyrometer—This instrument (Fig. 67) is of the nicol prism type described above. It is not a color matching instrument but a photometer in which monochromatic light from the object sighted is adjusted to equal intensity with a beam of similar light from an incandescent electric lamp. Light from the hot body enters the instrument through one aperture while through another enters light from the electric lamp. The 2 beams pass through an optical system whereby they are polarized in different planes, and rendered monochromatic; they then pass through a nicol prism into the eyepiece. The field seen by the observer is divided into 2 semi-circles, illuminated by rays from the hot body and the electric lamp respectively. The eyepiece, to which is attached the scale pointer, is rotated until the 2 semi-circles are equally illuminated, and the temperature is then read directly on the scale, which is engraved on a large circular plate forming a convenient shield. Ageing of the lamp is compensated by checking it against the standard amyl-acetate lamp supplied with each outfit, and altering the resistance accordingly. The pyrometer can be supplied fitted with one or more temperature scales, double scale instruments being provided with an absorbing screen, which is moved in front of the objective when using the higher range. Standard ranges for single scale instruments are 700 to 1400°F and 900 to 2000°C. For double scale instruments, the same two and others up to 4000°C.

Cambridge Disappearing Filament Pyromeyer—(Fig. 68). Same principle as the L & N and Siemens & Halske. Single or double range instruments. Standardization lamps supplied.

Foster Optical Pyrometer—A portable telescope combined with ammeter but separate from the battery. Disappearing filament type. Adjustment by controlling current through filament. A distinctive feature is the "lamp bridge unit" by means of which the whole scale is used, making it more open than it would be with a simple circuit: The lamp filament is made one of the arms of a Wheatstone bridge and the milliammeter is used as the bridge galvanometer. The method is that of the semi-potentiometer and possesses all of the advantages of that circuit. At the same time, the units of bridge and lamp combined are made interchangeable. Another model is made without a lamp bridge unit system and sells at a correspondingly lower price. Still another model is made with a separate indicator instead of the small one mounted on the telescope, and two rheostats are provided, one separate from the telescope for the coarse adjustment and the other one on the telescope body for close matching.

Chauvin & Arnoux (France)—A semi-self-contained disappearing filament instrument weighing a little over two pounds. Current supplied by either dry battery or light-weight storage battery slung from the shoulder. Distinctive features: (1) No dead space on scale; the zero at 600°C coinciding with beginning of perception of light from hot objects through the monochromatic filter. (2) Scale evenly graduated for 9/10 of its length. (3) Rheostat easily worked by one finger.

"Absolute" Types

"*Wedge*" (The Optical Pyrometer Syndicate)—This English instrument was referred to under "Methods" as being an example of the only type which does not use the comparison method. It is entirely self-contained and shaped like a plus mark, consisting as it does of a telescope and a long straight wedge—the housing in which the latter is moved up or down being of course vertical. The makers state, "The prism is made of specially prepared dark glass, so arranged that it cuts off the light emitted by a heated body at various temperatures. For example—in looking at a heated bar of iron, supposing the temperature to be 1000°C, then on turning the screw the thicker part of the prism comes gradually into the field of vision, the bar appears gradually a darker and darker color, till at a given point the color entirely disappears; this point gives the actual temperature. On looking at the scale, the pointer will be seen at 1000°C. A similar operation takes place in every estimation. Naturally a little practice is required to decide the exact moment when the color disappears, and here, of course, the practical eye of the operator comes into play."

"*Pyroversum*" (Ströhlein & Co., Germany)—Same principle as the English "Wedge" but simpler construction. It resembles a slide rule: A frame about 7″ long encloses a shaded glass ranging from clear at one end to opaque at the other. You look through a hole in the sliding eye-piece, which you push along the frame until the glow becomes invisible. You then read the temperature by the position of the slide on the scale along one edge of the frame.

"*P2*" (Same make)—Now for *the* simplest: Same idea as the Pyroversum but minus the sliding eye-piece. You hold the framed glass between your eye and the glowing object; you move it until the glow vanishes, and you mark the place on the graduated edge with your finger. Don't laugh: the glass is not red but *green* in its "effective wave-length" so that at very high temperatures (where λ_{max} lies in the visible spectrum and varies as the fifth power of the absolute temperature) the temperature can be measured fairly closely if you get the knack—and if the glowing source is nearly a black body, because standard emissivity corrections (for $\lambda = .65\mu$) are inapplicable.

6. Aspiration or Suction Pyrometers

Mention is made here of these devices, which are used for the measurement of gases at very high temperatures without exposing the sensitive element to the gases, dust and other destructive conditions. A suction or aspiration pyrometer is not itself an instrument. It is an apparatus or a set-up which embodies (usually) a thermocouple as the primary element. Note, however, that for extreme temperatures, the primary element is sometimes a rod of refractory material, the temperature of which is measured by means of an optical pyrometer. The suction is usually produced by means of an ejector, using compressed air as the impelling medium. An important application is the open-hearth. Another is the field of investigation of flame conditions.

7. Fusible Cones

Strictly speaking, fusion cones (also known as fusion pyrometers, pyrometric cones or pyrometer cones) are not instruments. They are not pyrometers. Their use is ridiculed by some engineers; attacked by many scientists. Nevertheless, their industrial importance wins them mention here. This importance is limited to certain high-temperature industries; notably to the ceramic industry. The combinations of temperatures, durations, atmospheres and other conditions at which cones reach their end points have recently been determined—thus ending their "blind" use and enormously increasing their value. End points vary with the cleanliness of the air in the furnace or kiln, with the rate of heating, and with other factors, thus doubling or tripling the tabulated data. The shape of modern cones has been standardized and differs from the old symmetrical disposition around a vertical axis. The complete series of cones includes sixty. No. 35 and No. 42 are pure known substances; the other fifty-eight are complex mixtures of minerals and prepared glass, the chemical and mineralogical composition of each being a trade secret, as well as its physico-chemical composition—crystalline, colloidal and amorphous particles, water of crystallization, dissolved or absorbed gases, etc. Beside these factors controlled by the maker there must be considered the factors controlled by the user, such as, (1) mounting and position; (2) oxidation of organic binder; (3) release of H_2O and CO_2; (4) rate of firing; (5) furnace atmosphere; (6) unknown factors controlled by standardized practice.

Twelve factors affect what takes place in the cone during firing. There is no space here for such a discussion—which is needed only for the most precise work. General statements on the characteristics of fusible cones have little value, and might cause confusion, because these characteristics are varied and complex. The only general statements that can be made are:

(1) Fusible cones may be used at temperatures above about 600°C or 1050°F, and up to somewhat less than 2000°C (3600°F).

(2) For industrial purposes it is necessary to standardize, as much as possible, the six controllable factors given above.

(3) Particular attention should be paid to protect the cones from contamination by products of combustion.

(4) Cones cannot be used by themselves to measure accurately temperature or rate of heating. However, in conjunction with the use of pyrometers for the measurement of rate of heating, and in the absence of serious contamination by furnace gases, they can be relied upon to "come down" at fairly definite temperatures.

(5) Cones are *more* than temperature indicators. They serve as guides to *duration* and other conditions. They will be referred to at greater length in the chapter on "Duration and Cycling."

NEW INSTRUMENTS

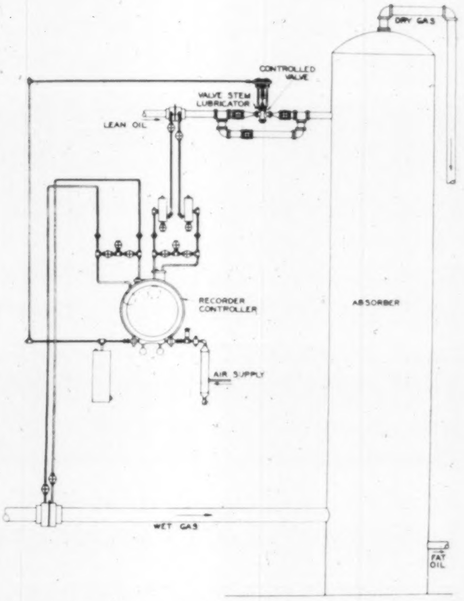
Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional information.

A Flow Ratio Recorder-Controller

(*Foxboro Company*)

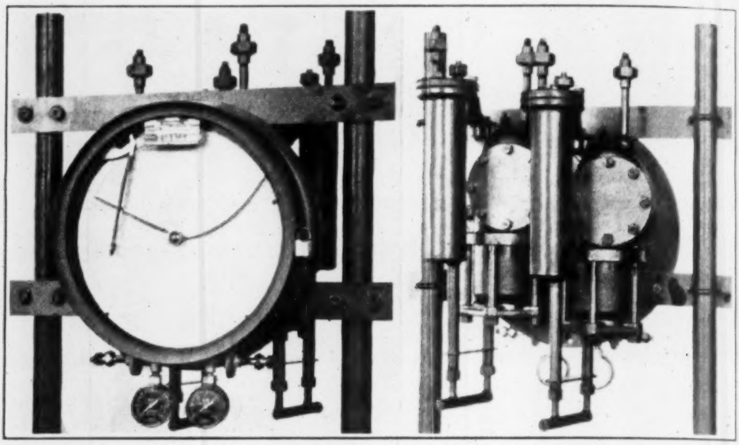
IN the oil industry it is often important to keep the flow of two liquids in direct proportion to one another. When one of these fluids is an uncontrolled variable the problem becomes difficult. This new Controller has solved the problem. This instrument gives the desired proportions at all times.



DIAGRAMMATIC LAYOUT OF RATIO CONTROLLER ON ABSORPTION TOWER

The Flow Ratio Recorder-Controller combines the sturdy, accurate features of the Foxboro Flow Meter with the close control features of the Foxboro Flow Controller. It is two instruments in one, so connected that the rate of flow of one fluid, as measured by the flow meter, controls the rate of flow of the second fluid. The flow meter constantly readjusts the control point of the flow controller thus keeping the two fluids in the desired proportions.

For example, in an absorption plant an orifice plate is placed in the rich-gas line to the absorption tower and the flow is measured. A controlled valve is placed in the lean-oil line and the flow of lean oil is controlled in direct ratio to the flow of rich gas. When the proper ratio is worked out, the ratio controller results in perfect operation. Maximum gasoline is absorbed without the waste of lean-oil. A ratio controller may also be used to control the ratio of steam to fat-oil, in the steam still. These are only a few of the many applications in the oil industry where a flow ratio recorder-con-



(Front) (Back)

troller can be put to work to maintain the required proportions at all times.

In fact, in any process where it is essential to maintain a constant flow ratio between two fluids, one of which is an uncontrolled variable the flow ratio recorder-controller will handle the problem by producing a more uniform product at a lower cost.

If both flows are controllable, the proportionate control should be used, as, for example, in lubricating oil bending.

* * *

The Connecticut Telephone & Electric Co., Inc., was recently purchased outright by the Connecticut Telephone and Electric Corporation. The vast plant, basic patents and special machinery were all acquired outright under the purchase as a unit of the Commercial Instrument Corporation.

Associated with the Connecticut company as other units of the Commercial Instrument Corporation are Jas. P. Marsh & Co., and the Sargent Company of Chicago, the Tiffany Mfg. Co., recently moved to Meriden from Newark, N. J., the American Paulin System, Inc., of Los Angeles, and the Carl A. Norgren Company of Denver. As the name implies, commercial instruments for a great variety of applications is the chief business of the corporation.

Commercial Instrument Corporation (until recently General Instrument Corporation) is a Vincent Bendix organization.

* * *

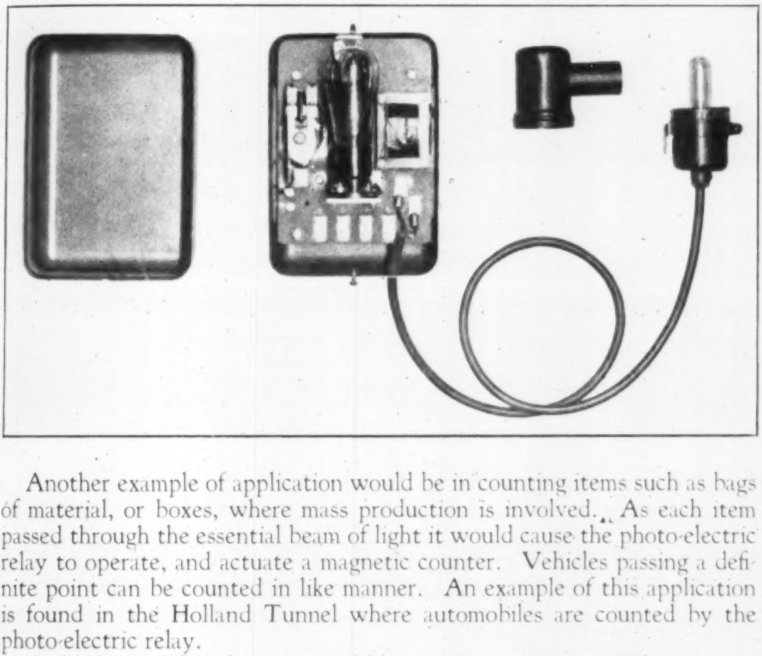
The Bailey Meter Company announces that it has transferred its office in Chicago, Illinois, to 20 North Wacker Drive Building. R. V. Knapp continues as branch Manager in this territory where he is assisted by a staff of mechanical engineers specializing in metering control and combustion problems.

The Photo-Electric Relay

(General Electric Company)

THE interruption of a beam of light controls the operation of industrial machinery and other devices by utilizing of a new device, the photo-electric relay, announced by the General Electric Company as an addition to its standard line of control equipment. The new relay is essentially a vacuum tube device, and uses both the photo-electric tube and the pliotron.

Many industrial or other operations in which a change of light is involved can be controlled by the new relay. In addition, many operations which can be arranged to cause a change of light can be so controlled. A machine, for example, which travels in a certain direction for a certain distance and is then stopped or reversed, is a typical application. When the traveling mechanism reaches its limit it would interrupt a beam of light falling on the photo-electric tube and thus cause the control device to function.



Another example of application would be in counting items such as bags of material, or boxes, where mass production is involved. As each item passed through the essential beam of light it would cause the photo-electric relay to operate, and actuate a magnetic counter. Vehicles passing a definite point can be counted in like manner. An example of this application is found in the Holland Tunnel where automobiles are counted by the photo-electric relay.

A third type of application would be sorting packages according to size, shape or reflecting power. Other examples would be stopping a paper machine when the paper breaks, aligning the paper on the rolls of the same machine, turning electric signs or signals on or off depending on the intensity of the outside light, deflecting packages on conveyors, and operating bag piling mechanisms.

The use of the photo-electric relay to control lights or illuminated signs according to the intensity of daylight is an interesting one. In an office or factory building it is always desirable to have a certain minimum light for the workers. During the day time, when the daylight intensity is high, no artificial lighting is needed. By using the new relay, the artificial lights can be turned on automatically when the daylight intensity falls below the predetermined minimum.

The new relay is designed for use in controlling an electric circuit in response to an increase or decrease in the amount of light falling on the photo-electric tube. The General Electric Company lists the following advantages resulting from its use:

1. It operates without shock or resistance to the progress or movement of the object which actuates it, or without impairing the accuracy of delicate mechanisms.

2. It can be located remotely from the equipment controlled, thus permitting mounting in small spaces around automatic machinery.

3. It is adjustable in sensitivity.

4. It can be used outdoors by mounting in a watertight enclosing case

5. It is easily installed, and its operation is easily adjusted or changed.

6. It can be operated at high speeds, 100 times a minute being an approximate maximum.

For some applications it may be necessary to select carefully a suitable light source and optical accessories, but for many cases the light source may be a domestic Mazda lamp with or without a simple reflector and shield.

The standard electric supply for the relay is 110/120 volts, 60-cycles, alternating current. The device may, however, be built on demand for other frequencies or voltages, and a similar device for operation where only direct current is available can be obtained.

The operation of the relay is described as follows: With a voltage of proper polarity and magnitude applied between the two elements of the photo-electric tube, the current it passes is proportional to the amount of light shining on it. This current (of the order of a few micro-amperes) is amplified by a pliotron. The sensitive relay is connected in the plate circuit and is energized or de-energized in accordance with the amount of light on the photo-electric tube. The contacts of the relay control the coil circuit of the contactor. When the relay in the plate circuit of the amplifier is energized, it will first open its normally-closed contacts and then close the normally-open contacts. This relay, therefore, either makes or breaks the coil circuits of the contactor depending on how it is connected.

When the contactor is de-energized approximately ten watts is required by the device, and when the contactor is energized approximately 30 watts is required.

L101 STUDENTS' SPECTROMETER

THIS small Spectrometer embodies every necessary feature usually found only in expensive grades of instruments. It is not only useful for the student but will in many cases serve for research work.

Details on request

THE GAERTNER SCIENTIFIC CORPORATION
1201 Wrightwood Avenue • Chicago, U. S. A.

Knock Testing Apparatus

(Ethyl Gasoline Corporation)

THE unit consists of a heavy cast iron base on which are mounted the engine, synchronous generator and cooling system, together with a control panel which carries the instruments and control switches. A concrete foundation 38″ x 41¼″ x 26″ high is required for the engine assembly which is shipped with all accessories properly mounted on the cast iron base. All wiring is carried in flexible conduit in the base and the only wiring required during the installation of the apparatus is the connection to the panel of the wires in two pieces of flexible conduit furnished with the engine and of the leads from the power supply lines to the synchronous motor starter switch on the panel.

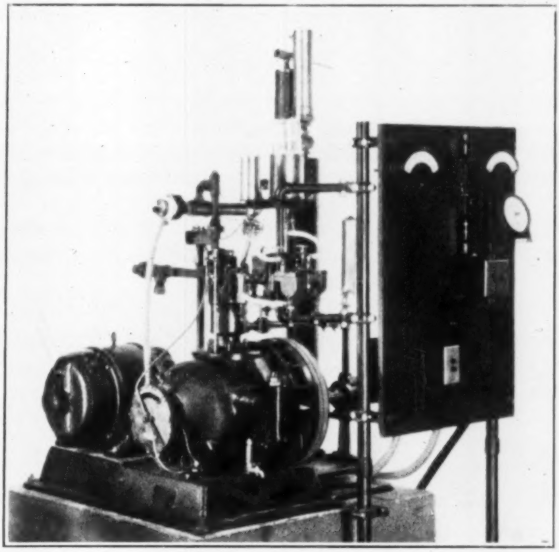


Fig. 1

The bore of the engine is 2½″ and the stroke 4⅝″. On account of its small size the engine uses only a very small quantity of fuel in a long period of time, hence small samples may be accurately tested and expensive standardization fuels may be used quite economically.

The flywheel weighs 200 lb., its inertia causing the crankshaft to rotate at practically constant angular velocity during the four cycles of engine operation. Grooves for the V-belt drive for the synchronous generator are milled directly into the flywheel.

The ignition system is specially designed to maintain constant spark advance at all times and furnish a spark of sufficient intensity to fire the charge at any compression pressure which may be obtained on the engine. A pivotless breaker of the aviation type is driven directly by the crankshaft. The absence of blacklash characteristic of camshaft ignition drives and the elimination of all pivot bearings in the timer mechanism permit the maintenance of any desired spark advance within a very small fraction of 1°. A neon tube spark protractor of large size forms an integral part of the breaker mechanism and an adjusting screw is provided for the regulation of the spark advance.

Engine power is absorbed by a special alternating current synchronous generator which also cranks the engine. A special 70 volt direct current winding in the generator supplies direct current for the ignition system and for the operation of the knock measuring instruments.

Easily removable V-belt generator pulleys are available in several sizes to permit operation at different speeds. A spline is set into a milled groove in the cast iron base and engages a similar groove in the base of the synchronous generator. The spline maintains the generator in proper alignment with the flywheel while pulleys are changed or the belts tightened. A simple adjusting screw permits the maintenance of the desired tension on the belts. The feet of the generator are slotted and provided with clamping screws.

The cooling system provides the advantages of both evaporative and circulated liquid cooling. A long liquid column attached to the cast iron base supports a reflux condenser. A circulating pump, directly-driven by the crankshaft, forces eight gallons of liquid per minute into the lower jacket connection. Since the liquid in the system is always maintained at its boiling temperature, the heat absorbed by the liquid in passing through the cooling jacket generates bubbles of vapor. The mixture of liquid and vapor passes from the cooling jacket into a separating chamber in the cooling liquid column and the vapor is condensed by the reflux condenser.

A jacket temperature of 212°F. is used for testing automobile fuels and a temperature of 350°F. for aviation fuels. The higher temperature is secured by a mixture of ethylene glycol and water. Since the temperature of the vapor phase of a mixture of ethylene glycol and water is changed very much by a small change in the percentage of water present in the liquid, it is necessary to be able to control the concentration of water quite closely to obtain a jacket temperature of 350°F. A three-way cock mounted on the top of the condensing column permits the vapor from the cooling jacket to be fed into a spiral fractionating column having an equivalent length of 8 ft. of straight flat tubing. Excess water may be evaporated off until the desired boiling temperature is obtained, without the loss of ethylene glycol. When the desired temperature is reached the three-way cock may be turned to permit the vapor to pass into the reflux condenser, after which the desired temperature is automatically maintained.

On account of the large temperature difference between the outside air and the cooling liquid when high jacket temperatures are used, it is impossible to maintain a temperature of 350°F. by engine heat alone if throttle openings of less than 8° are used. To permit operation of the engine at very small throttle openings, a three-heat immersion heater is inserted in the cooling liquid line between the engine cylinder and the liquid column. With the switch on the "Low" or "Intermediate" positions the heater may be used to supplement the heat supplied by the engine to raise the liquid to its boiling temperature and with the switch on the "High" heat position the heater may be used to secure rapid warming up of the engine.

The liquid column is insulated with 85% Magnesia covering and prevents the temperature of the liquid falling below the boiling temperature while it is in the column. An armored mercury thermometer with open scale is screwed into the line which connects the pump with the cooling jacket of the engine.

The fractionating column may also be used to secure a temperature of 212°F. in regions of high altitude where water alone boils at a considerably lower temperature.

The control panel carries the magnetic starter for the sychronous motor, tachometer indicator, electrolytic cell, knock intensity meter (described below), stop clock, a fixed-tap resistance for supplying six volts to the ignition system, and a variable voltage resistance for the knock measuring instruments, as well as the necessary control switches and fuses.

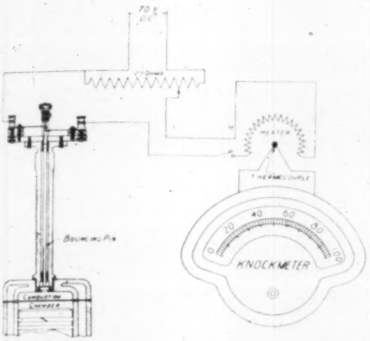


Fig. 2 Bouncing Pin Circuit with Knock Indicating Millivoltmeter.

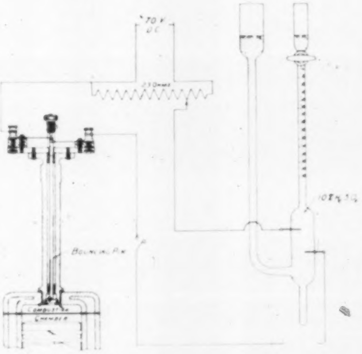


Fig. 4 Bouncing Pin Circuit with Electrolytic Cell.

Fig. 2 shows the circuit used. The bouncing pin current flows through a fine resistance wire placed in such relation to a thermo-couple of definite size that a continuous, non-fluctuating indication of temperature is obtained which is proportional to the square of the average knock intensity as measured by electrolysis. Among the advantages of the knock intensity meter over the electrolytic cell may be enumerated:

1. Greater percentage of scale indication for a given difference in intensity of detonation.
2. Rapid determination of the air-fuel ratio for maximum knock, since the location of this point requires only the continuous variation of the float level until maximum needle deflection is obtained.
3. Greatly decreased time required for the testing of samples. By actual comparative test it is possible to rate three times as many samples on the new machine as on the old in a given length of time.

Fig. 3 shows the circuit provided for the measurement of knock by electrolysis in case it is desired to use this method. A switch located on the panel permits the rapid change from one system to the other. The sliding tap on the resistance mounted on the rear of the panel permits any percentage of maximum scale reading to be obtained for a given knock intensity on either the electrolytic cell or the knock intensity meter.

Both cylinder temperature and intensity of detonation have an effect on the comparative rating of some types of automobile fuels and of almost all types of aviation fuels. For this reason it has been found necessary to specify compression ratio, compression pressure, jacket temperature and spark advance for both motor and aviation fuels. The new type engines are uniform in their characteristics and produce the same intensity of detonation for a given setting of these variables.

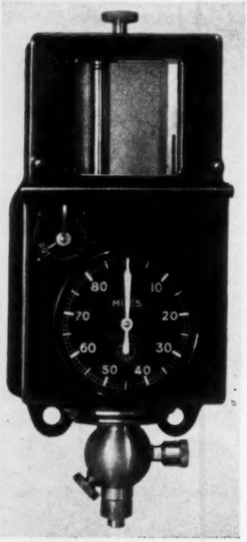
Acceleration & Deceleration Recorder

(R. W. Cramer & Co. Inc.)

THIS is a scientific instrument of practical application in the testing of automobiles, busses, trucks, street cars, motors, engines, hoists, etc. In its automotive application it is operated from the speedometer drive shaft, or through a fifth-wheel; it marks on a direct-reading rectilinear chart a record of the following test data:

1. Rate of Acceleration, in Miles per hour per second
2. Number of seconds }
3. Number of feet } to go from one speed to another, or from standstill.
4. Rate of Deceleration, in Miles per hour per second
5. Number of seconds }
6. Number of feet } to brake from one speed to another, and to a full stop.

The human factor is entirely eliminated from the record. The operator only has to run the car, and need not be on the alert for a marked spot on the road, or for a certain point on the speedometer. The instrument itself automatically measures the distance on the chart, and records every second and every speed. The car is accelerated to any speed, or the brakes are applied at any speed, and only that part of the chart is used which comprehends the required range. By the nature of the design of the instrument, the calibration and accuracy are absolutely permanent, and are not affected by surge, inertia, momentum, changes of temperature or other physical forces.



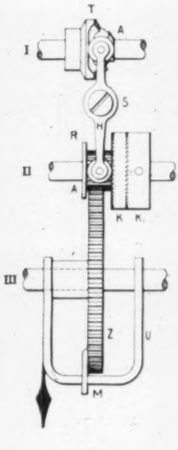


Fig 2

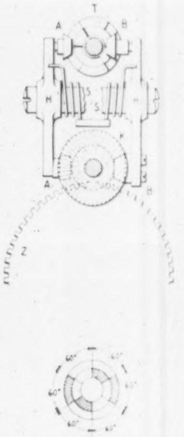


Fig 3

Fig 1 (at right). Front View of Instrument

For testing equipment other than vehicles, the recorder is driven from some part rotating at a speed proportional to the movement to be recorded, through a flexible drive shaft, gear train, pulley and belt, or friction wheel.

The principle of the mechanism is that of time-distance-speed integration. A time-measuring shaft (I in Fig. 2) is in gear with a clockwork mechanism and turns at a constant speed. A distance-measuring shaft (II in Fig. 2) is in gear with the driving spindle of the instrument and turns at a rate proportional to the speed of the vehicle. The integration of these two measuring elements is accomplished through a system of three cams (T, Figs. 2, 3) on the time shaft and of three clutches (KK_1 in Figs. 2, 3) on the distance shaft, through conjugating levers (H in Figs. 2 and 3) actuated by the shape of the cams to engage and disengage the clutches through successive seconds. These cams serve to span successively time units of exactly one second each, during which the time shaft and the distance shaft are conjugated, the resulting integrated speed being measured by the deflection of one of three measuring wheels (Z, in Figs. 2 and 3) which carries along in its movement a stirrup (U, in Fig. 2) under spring tension. The movement of this stirrup is transmitted to the indicating pointer, and by means of gears and a toothed rack to the recording scriber arm.

In order to secure speed measurement and speed indication during every second of movement, there are three such complete mechanisms, each composed of a cam, clutch and conjugating lever, whose cycle of operations start successively one second apart. The stirrup, however, is common to all three sets.

If we suppose the first set to come into operation first, the stirrup will be carried round for one second, moving the pointer and recording scriber with it, and will be held for another second during which the measuring wheel of the second set will be moving round to take up the stirrup at the beginning of the third second. The action of the measuring wheel of the third set will be, a second later, similar in effect, and the cycle of operations will then be continued by the first set, and so on.

The stirrup is always carried by whichever measuring wheel has the greatest angular deflection. If the speed is increasing, the stirrup will be moved on farther in the successive seconds; but if it is diminishing, the stirrup will be moved back. Thus the pointer as well as the recording scriber are always set anew every second to the mean speed of the last preceding second. It naturally follows that in acceleration or deceleration runs the mean speed of each second is recorded on the chart by successive steps, up or down.

The movement of paper is in proportion to distance travelled, at the rate of 2640 mm. per mile, or 1 mm. of paper for every 2 ft. traveled.

The graph is drawn uninterruptedly in the form of successive steps up or down, the ordinate from the zero line of the chart to any horizontal speed mark being the speed in miles per hour. The rate of acceleration or deceleration in miles per hour per second is the difference in height between any two successive speed ordinates.

Since the chart moves concurrently with the measurement of speed, the recording of which will take place only in the succeeding second, it is obvious that in order to read on the chart the distance covered during one second at any speed the length of paper fed on the previous step must be measured.

To determine the total number of feet traveled by the vehicle on an acceleration run, it is only necessary to measure the length of paper fed from the first second of the run to the beginning of the line marking the top speed (on the graph illustrated, from A to E).

To determine the total number of feet traveled by the vehicle on a deceleration run, measure the length of paper fed from the first second of the run to the end of the graph (from E to J).

In both cases, multiply the number of millimeters of paper by 2, and the result is the total number of feet traveled.

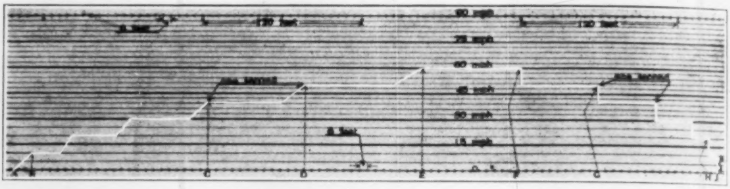


Fig. 4. Chart ($\frac{3}{5}$ Actual Size)

By referring to the chart illustrated (which by the way is not an actual run but was drawn up to illustrate the salient points) it will be seen that on the acceleration run there are 6 steps up to 60 MPH; i.e., it took 6 seconds to attain that speed from standstill. The length of paper from A to E (which on an actual full-scale chart would be 154 mm.) represents the number of feet covered in accelerating to 60 MPH; that is: 308 ft. The length of paper, E to J, (on a full-scale chart being 113.6 mm.) represents the number of feet covered in braking from 60 MPH to a full stop; that is: 227.2 ft. The distance A to B is the feet covered the first second at a mean speed of 10 MPH; C to D the feet covered during one second at a mean speed of 50 MPH; E to F the feet covered during the first second of the deceleration run at a mean speed of 50 MPH; F to G the feet covered during one second at a mean speed of 40 MPH; H to J the feet covered in the last second of the deceleration run at a mean speed of 5 MPH. The final return of the scriber to zero at the end of the last second vehicle movement is represented by K to L. This is simply the one-second lag between the measuring and recording functions and does not represent any movement of the vehicle.

An interesting development is the application of this instrument to the flight-testing of airplanes, for recording take-off and landing speeds—important factors in plane performance which until now have had to be guessed at more or less, owing to the lack of suitable scientific instruments. In this application, the instrument is operated through a "third-wheel" attached on the plane at some suitable point, generally on one of the struts. It records the following performance data:

1. Speed of plane at moment of take-off and landing, in M. P. H.
2. Lengtn of take-off and landing runs, in feet.
3. Elasped time of take-off and landing, in seconds.

* * *

It is common experience that next to possessing information the ideal desideration is to know where to find it. This is especially true at present when the vast amount of information probably available on almost any subject is so great as to lie beyond the capacity of an individual. The problem usually is to know where to find what is wanted.

The world-wide demand for informaton of all kinds has grown so rapidly that one is often at his wit's end to know where to look for it.

If you are looking for instrument information—you will find it is in INSTRUMENTS. Subscription 2 years—$3.00

CATALOGUE LIBRARY

Check the publications you want. Remove the page and send with coupon to INSTRUMENTS They will be forwarded to you without obligation.

SEND COUPON FOR LITERATURE DESIRED

INSTRUMENTS PUBLISHING CO., 1117 Wolfendale St., Pittsburgh, Pa.

Please send us, without obligation, the literature checked herewith.

Company ______________________________

Name ______________________________

Address ______________________________

Title ______________________________

BLAETTER FUER UNTERSUCHUNGS—UND FORSCHUNGSINSTRUMENTE. The January issue of this house organ contains the following articles: The preparation of micro-sections of stone, ore, glass, bone, etc; A new Vertical Illuminator. This is printed in German. Emil Busch, A. G., Rathenow, Germany.

COMBUSTION CONTROL. Feature No. 12 of this series is entitled "Increases the Life of Refractories." Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

COMPARATORS AND COLOR DISCS FOR THE ANALYSIS OF WATER SEWAGE INDUSTRIAL WASTES. List No. 601 describes instruments and accessories for this purpose. Hellige-Klett, Inc., 179 East 87 St., New York, N. Y.

DIVIDING MACHINES. Preisliste V illustrates a number of automatic circular dividing machines, micrometer dividing machines, device for the inspection of divided circles, etc. This is printed in German. Gustav Heyde, Kleiststr. 10 Dresden, Germany.

DUO-STAT. Instruction booklet giving information on installation and operation of the Duo-Stat for regulating steam heating plants.

ELECTRICAL INSTRUMENTS. Bulletin No. 300 covers portable, direct reading, slide wire ohmmeters and circuit testers. Bulletin No. 210 covers direct current portable instruments: ammeters, milli-ammeters, voltmeters, milli-voltmeters, volt-ammeters, shunts, multipliers. Roller-Smith Company, 233 Broadway, New York, N. Y.

GAS DETECTOR. Leaflet describes the Jones gas detector for determining the approximate explosive content or an oxygen deficiency of atmospheres in confined spaces. Mine Safety Appliances Co., Braddock Ave & Thomas Blvd., Pittsburgh, Pa.

MERCOIDS. The April 1930 issue of this house organ is dedicated to the new plant of the Mercoid Corporation. An article on "Economics of Automatic Control of Unit Heaters" is included. The Mercoid Corp., 4201 Belmont Ave., Chicago, Ill.

TYCOS ROCHESTER. The April issue of Tycos-Rochester contains the following articles: Uncle Sam Attempting to solve Ancient Problem; Science Seeks to Hatch Artificial Weather; Nothing in the World Colder than this Place; Fathoming Neptune's Secret; Power from Ocean Temperature; Actual and Normal Weather Conditions; Navy Aerologists studying Weather Puzzles. Taylor Instrument Companies, Rochester, N. Y.

PULL ROD DYNAMOMETER. Leaflet illustrates the Martin-Loomis pull rod dynamometer for measuring pull rod loads. Martin-Decker Corp., 3441 Cherry Ave., Long Beach, Cal.

PUMP DYNAMOMETER. Twelve page bulletin describes and illustrates this instrument for recording pumping conditions in oil wells. Martin-Decker Corp., 3441 Cherry Ave., Long Beach, Calif.

DEMAND METERS. Catalog GEA-612 illustrates various types of demand meters, their construction, operation and characteristics. General Electric Company, Schenectady, N. Y.

ADVERTISING SAFETY PRACTICES. A booklet discussing the principles, form, appeal and media to be used in this type of publicity and illustrated with photographs of effective bulletin board and other displays is being distributed by the Policyholders Service Bureau, Metropolitan Life Insurance Co., One Madison Ave., New York, N. Y.

THE FOG HORN. The April issue of this house organ briefly discusses moisture control in printing plants. It also describes the turbo humidifier. Parks-Cramer Co., Fitchburg, Mass.

RECORDING INSTRUMENTS. Bulletin GEA-1061B supersedes GEA-1061A covers recording instruments for alternating and direct current. General Electric Company, Schenectady, N. Y.

GENERAL RADIO EXPERIMENTER. The March Issue of this publication contains the following: The Standard-Signal Method of Measuring Receiver Characteristics; and Straight-Line Wavelength, Straight-Line Frequency, and Straight-Line Capacitance Condensers. General Radio Company, Cambridge A, Mass.

CURVE TRACER. Circ. 7460 G 95-330 illustrates the Rosa Curve Tracer. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

TORSION-DYNAMOMETER. Leaflet illustrates a number of applications of the Bamag Torsion-Dynamometer and briefly describes its operation. This is printed in German. Berlin-Anhaltische Maschinenbau Aktienges, Dessau, Germany.

IMMERSION PYROMETERS. Leaflet illustrates the application of the immersion pyrometer to measuring the temperature of type metal for newspapers, publishers, smelters, electrotypers, and type founders. Illinois Testing Laboratories, Inc., 141 W. Austin Ave., Chicago, Ill.

ACCELERATION AND DECELERATION RECORDER. Bulletin describes the Hasler Tel. recorder. R. W. Cramer & Co., Inc., 136 Liberty St., New York, N. Y.

TECHNICAL MEASURING INSTRUMENTS. Bulletin gives information on the complete line of instruments manufactured by Lehmann & Michels: Instruments for indicating power; Shaft horse Power; Vibration Study; Material Testing; Special Testing. This is printed in English. Lehmann & Michels, Hamburg-Altona, Abt. I, Germany.

THE LABORATORY. Volume Three, Number Two of the Laboratory contains the following: Lavoisier, Founder of Modern Chemistry; Carbon Determination in High Sulphur Steels; and several instrument descriptions. Fisher Scientific Company, 711 Forbes St., Pittsburgh, Pa.

GAS SERVICE JOURNAL. The March issue of this organ contains the following: From Pipe-Dreams to Gas-Pipes. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

MICROTAST INDICATORS. Leaflet covers Krupp Mikrotast Indicators. Coats Machine Tool Co., Inc., New York, N. Y.

SAFETY SWITCHES. Catalog 226 illustrates and describes a large number of safety switches. 72 pages. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

ELECTRO-MAGNETIC WELL SURVEYING INSTRUMENT. Reprint from the Petroleum Engineer describes this device for measuring the vertical deflection in a well or bore hole. Driftmeter, Inc., 616 Exchange Bank Bldg., Tulsa, Okla.

GRAPHIC TIME RECORDERS. Bulletin 330 gives a full description of the Esterline-Angus time recorder, as well as illustrations of several applications. Esterline-Angus Company, Speedway Ave., Indianapolis, Ind.

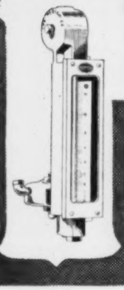
COMBUSTION CONTROL. Thirty-two page booklet discusses combustion control for boiler furnaces and describes the L & N metered combustion control. Bulletin No. 660, 1930. No. 6-Power Plant Series. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

JIG BORERS. Catalog No. 546 illustrates the special features of the jig borers of the Cociete Genevoise d'Instruments de Physique. The R. Y. Ferner Company, Investment Bldg., Washington, D. C.

SOCKETS AND TUBES FOR PYROMETERS AND THERMOMETERS. Leaflet illustrates a wide variety of types, lengths and metals for a variety of services. Hills-McCanna Company, 2349 Nelson Street, Chicago, Ill.

NON-FERROUS ALLOYS AND PRODUCTS. Twenty-four page booklet gives information on various non-ferrous alloys: physical properties, corrosion resistance, machining, analysis, etc., Hills-McCanna Company, 2349 Nelson Street, Chicago, Ill.

GRAPHIC INSTRUMENTS. Bulletin No. 830 announces a new line of graphic instruments for alternating and direct current, supplied in switchboard, wall and portable types. Roller-Smith Company, 233 Broadway, New York, N. Y.



Flow Meters

THE MERIAM Co.

MADISON AVENUE at 112th STREET
CLEVELAND, OHIO

ELECTRICAL MEASUREMENTS *of* NON - ELECTRICAL MAGNITUDES

We will cooperate with reputable corporations and individuals in the development of new methods and apparatus for measuring various physical quantities by electrical means. *Correspondence invited.*

RUBICON COMPANY

Makers of Precision Electrical Measuring Instruments

29 North Sixth Street, Philadelphia, Pa.

SCHOPPER

Precision Testing Machines

"STANDARD THE WORLD OVER"

For Testing ALL MATERIALS

Abrasion
Absorption
Bending strength
Bursting strength
Density
Detrition
Elasticity
Elongation
Expansion
Fatigue
Folding endurance
Freeness
Hardness
Humidity
Impact strength
Moisture content
Permanent set
Porosity
Shock
Speed
Tensile strength
Thickness
Torsion resistance
Weight

Registered
Trade Mark

Write for Descriptive Literature

H. Z. SCHNIEWIND

72 Duane Street New York, N. Y.

Sole Agent U. S. A. and Canada

Oxweld

Portable Tensile Testing Machine

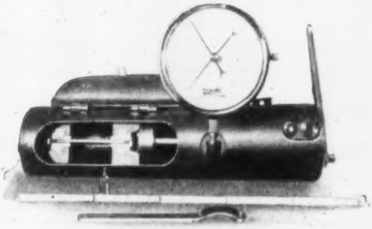
SOUTHWARK
Designed and Built

This new Portable Tensile Testing Machine, brings accurate testing directly into the field of operations. Ideal for quickly determining the efficiency of welded seams.

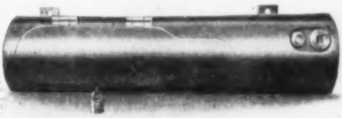
Also furnished in the Compression Type.

Net Weight 165 Lbs.
Capacity 40,000 Lbs.

SOUTHWARK
Foundry and Machine Co.
400 Washington Ave. Philadelphia, Pa.



Readyfor Operation



Closed for Shipment

Developed in Collaboration with
UNION CARBIDE and
CARBON RESEARCH LABORATORIES

CURRENT LITERATURE REVIEW

Abstracts on instruments and devices for measurement, inspection and control.

The Technology Department, Carnegie Library, Pittsburgh, Pa., will furnish photostats of material abstracted here. Negative prints are 35 cents per page, plus 10 cents for mailing (first class). All orders should be paid in advance. The library is not responsible for loss in mails

MISCELLANEOUS

New Methods of Measuring and Their Applications (Neue Messmethode und ihre Anwendungsmoeglichkeiten) F. Toedt. Messtechnik, Jan. 1930, pages 5-6.

The disadvantages of present methods of corrosion testing are given. A new method for the direct indication of corrosion on an electrical indicator is described, as well as its application for testing protecting coatings and for the indicator of the content of oxydizing substances.

A Plea for the Preservation of Old Instruments. T. H. Court. Instrument World, March 1930, pages 301-304.

The plea is made in order to preserve these instruments for their historical and educational value.

A Service Organization Within a Service Organization. C. F. Hirshfeld & J. H. Walker. Detroit Edison Synchroscope, Feb. 1930, pages 397 403.

Research problems carried on by the Research Department of the Detroit Edison Co. are described.

Equipment for Testing Steam Turbines. (Die Pruefeinrichtungen fuer Dampfturbinen im grossen Prueffeld des Muelhemier Werkes der Siemens Schuckert Werke). A. Bross. Siemens Zeitschrift, Dec. 1929, pages 872-873.

The article considers equipment for testing steam turbines.—G. N.

Controlling Heating and Ventilating in the Berlin Operas. (Fernthermometer und Klappefernstellanlagen in den Berliner Staatstheatern). E. Kuhn. Siemens Zeitschrift, Dec. 1929, pages 873-877.

Description of heat and ventilation control from a central station, as installed in the State Theatres of Berlin.—G. N.

To Etch Glass. Photographe, Oct. 5, 1929, page 425.

Glass may be etched with the following solution: (A) sodium fluoride, 80 grams; sodium sulfate, 7 grams; water, 500 c.c. (B) zinc chloride, 14 grams; hydrochloric acid, 65 c.c.; water, 500 c.c. For use, mix equal parts.—Abs. Bull. Kodak Res. Labs.

The Manometer Tube Spring (Die Manometerroehrenfeder) P. Schoenefeld. Messtechnik, Jan. 1930, pages 9-10.

The method of operation of a tube spring with an elliptical cross-section is described.

A Contribution to the Theory of Cooling Optical Glass. (Ueber einen bedeutsamen Beitrag zur Theorie der Kuehlung und Feinkuehlung optischen Glases). J. Fluegge. Glastechnische Berichte, June 1929, pages 102-106.

An extended abstract of an article "The Annealing and Re-annealing of Glass" by W. Hampton, appearing in Transactions Optical Society. Vol. 26, pages 14-30; Vol. 27, page 161-180.

MAGNETISM

A New Magnetometer. Canadian Mining Journal, Jan. 24, 1930, pages 100-102.

A description of the principles, construction and purposes of the Hotchkiss Superdip magnetometer, which detects and measures the comparative magnitudes of variations in the earth's magnetic field. Four types of service include: (1) to locate directly certain deposits of such natural resources as iron, magnetite, hematite, limonite, pyrrhotite, nickel, salt, etc.; (2) to locate indirectly certain deposits of such natural products as gold, platinum, and tin in placers, and such ore deposits as are associated with veins, dikes, sheets, contacts, faults, etc.; (3) to do rapid reconnaissance work, both regionally and locally, in advance of other geophysical instruments; (4) to locate such geophysical features as faults, folds, buried ridges, metamorphic changes, etc.—W. H. B.

Standards for Testing Magnetic Permeameters. Raymond L. Sanford, Bureau of Standards Journal of Research, Feb., 1930, pages 177-188.

The testing of magnetic permeameters is greatly facilitated by the use of calibrated test specimens used as standards. The test method employed for calibration must be an absolute one whose accuracy can be estimated without reference to any other method. In order to be suitable for use as magnetic standards, test specimens must conform to certain requirements the most important of which is magnetic uniformity along their length. The paper gives reasons for adopting the Burrows permeameter as the standard method for calibration, shows the effect of nonuniformity in the specimens, and gives the characteristics of four bars which have been found to be sufficiently uniform to warrant their use as magnetic standards.

Measurement of Strong Magnetic Fields with the Zeeman Effect. M. C. Michels. Elektrotechnische Zeitschrift, Sept. 26, 1929, page 1595.

The zinc spark lines 4810, 4722, and 4680 were used and the wave length of the outer components was measured. An accuracy of 1 or 2 per cent for fields over 10,000 gausses is believed with a good optical system accurately aligned.—Abs. Bull. Kodak Res. Labs.

A New Fluxmeter (Ein neues Flussmeter). G. Stein. Electrotechnik und Maschinenbau. Dec. 15, 1929, pp. 1097-1102.

Describes an instrument, developed in the laboratories of the A. E. G. Transformer Works, which permits the direct determination of magnetic flux by measuring an equivalent current by means of an ammeter and oscillograph coil. Constructed as a three phase reactance coil, it can also be used for precision measurements.—M. S.

INSPECTION

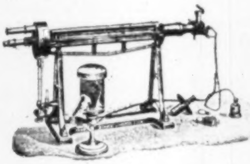
Gaging Small Interchangeable Work. L. E. King. Machinery, Dec. 1929, pages 289-293.

Discusses the development and application of a gaging system intended for use in the manufacture of low priced clocks and watches. Material also applicable to other small mechanisms.—R. H. P.

Plain and Thread Plug and Ring Gage Blanks. Miscellaneous Publication No. 100, Bureau of Standards, 45 pages, 1930, 15 cents.

The American Gage Design Standards are detailed by description, line drawings, and dimensional tables.

Polarimeters for Sugar Analysis



Made by
FRANZ SCHMIDT & HAENSCH

Write for literature to
Sole Distributors

AKATOS, INC.
Engineering Building
114-118 Liberty Street
NEW YORK CITY

Tungsten and molybdenum wire and rods from .0005" up. For radio receiving and transmitting tubes, incandescent and arc lamps, lead-in wire, high temperature electric furnaces, special resistances, etc., also fine wire drawing, high vacuum pumps-mercury or oil.

High Vacuum laboratory.

Special neon and gas filled tubes for television, luminous tubes, high tension indicators, talking pictures, stroboscopes, ultra-voilet and infra-red lamps.

KH photo-electric cells.

KH recording lamps.

Equipment for high vacuum laboratories, radio tubes and incandescent lamp factories.

High frequency apparatus. Bombarding machines. Parts for building high frequency apparatus. Quenched tungsten spark gaps. Open tungsten spark gaps. High voltage condensers. Special transformers made to order. High temperature furnaces, annealing ovens, etc.

ARGCO LABORATORIES, INC.
150 WEST 22nd ST. NEW YORK, N. Y.

Electrical Measuring Instruments

for use at communication frequencies (0 to several million cycles per second)

Frequency Standards · Tube and Tuning Fork Oscillators · Resistance Boxes Bridges · Calibrated Inductors · Variable Air Condensers · Voltage Dividers Attenuation Networks · String Oscillograph · Thermionic and Oxide-Rectifier Voltmeters · Accessories: Rheostats, Transformers, Relays, etc.

GENERAL RADIO COMPANY
Manufacturers of Electrical Measuring Apparatus
for Laboratory and Industrial Use
CAMBRIDGE A, MASSACHUSETTS

BAKELITE MOULDING

Will add to the appearance, improve the quality, insure exactness and lower costs in fine instruments. Our engineering department is at your service both in the designing and making of your moulds and in supplying the finished parts. We are the largest exclusive Bakelite Moulders in the Central West. Let us help you with your production problems. Send for our Catalog.

CHICAGO MOULDED PRODUCTS CORP.
2146 Walnut St. : Chicago, Ill.
Subsidiary to Plymouth Mfg. Co.

GASES, AIR & STEAM

Air Flow Through Suction Valve of Conical Seat. Part II. Analytical Investigation. Keikit Tanaka. Report No. 51, Aeronautical Research Institute, Tokyo Imperial University, pages 362-424.

This paper deals with the experimental research and its analystical investigation of the air flow through suction valve of conical seat. And in the present article of Part II its analytical investigation is dealt with. The four flow configurations I, II, III and IV, which were studies in the experimental research of Part I (Report of this Institute No. 50) and are shown, were investigated here analytically assuming them as potential flow and their motions to be two dimensional. They were solved in orders of the flow configurations III, II, I and IV with appropriate approximations. Some modified flow states which were derived from the variations of the profiles of valve and seat were also solved analytically. The results of these solutions were compared with the corresponding experimental results obtained in Part I and some analytical explanations were also given upon them.

Pressure Considerations and Linear Transmission of Steam, Air and Gas Meters (Druckberuecksichtigung und Linearuebersetzung an Dampf, Lutt, und Gasmessern) H. Hoffmann. Messtechnik, Oct. 22, 1929, pages 271-274; Dec. 1929, pages 329-334.

The size of the errors without considering the pressure is discussed, as well as the influence of a drop in pressure. Methods for correction as well as the principal errors of different solutions are included.

Electric Tester Shows Presence of Inflammable Gas. Scientific American, Jan. 1930, pages 87-88.

This is a more complete description of the electrical gas tester described in the June, 1929, Scientific American. The instrument works satisfactorily with the following gases: methane, ethane, propane, butane, pentane, hexane, gasoline, acetone, ethylene, propylene, butylene, benzol, toluol, ethyl acetate, propyl acetate, butyl acetate, ethyl ether, methyl alcohol, propyl alcohol, butyl alcohol, ethylene dichloride, ethylene oxide, carbon monoxide, and hydrogen sulfide.—Abs. Bull. Kodak Res. Labs.

New Gas Detector. Electrical Review, Jan. 10, 1929, page 88.

Instrument, produced by J. H. Naylor, Ltd., is claimed to detect and measure accurately the presence of any combustible substance in the atmosphere. Gives accurate readings up to 0.05% inflammable gas. Makes use of the principle of the combustion equation of methane in air.—M. S.

SPEED, ACCELERATOR & TIME

A New Inertia-less Chronograph. P. A. Cooper. Longdon, Edinburgh & Dublin, Philosophical Magazine & Journal of Science. Dec. 1929, pages 1100-1112.

Gives a detailed description of a new type of galvanometer, employing a quartz fiber suspension, and suitable for use on direct or alternating current circuits. Calibration curves for the instrument are given. Gives empirical formulae to determine the current passing through the instrument in terms of deflection produced.—R. H. P.

A New Timing Disc for the Oscillograph. A. Schreiber. Bell Laboratories Record, Mar. 1930, pages 333-335.

A motor driven disc allows a beam of light to fall on the oscillograph paper every hundredth of a second to form timing lines.

Registration of the Oscillations of a Free Pendulum. G. Ferrié. Monthly Notices Royal Astronomical Society, Oct. 1929, pages 713-718.

A method for the registration of the oscillations of a free pendulum without being connected with any mechanical registering device is described.—Abs. Bull. Kodak Res. Labs.

New Spark Microchronograph. F. Hope-Jones. Monthly Notices Royal Astronomical Society, Apr. 1929, pages 615-617.

After referring to improvements that have been made recently in clocks, wireless methods of comparing clocks and time signals at distant observatories, the author describes a very accurate spark microchronograph made by A. L. Loomis, which gives promise of great accuracy.—Abs. Bull. Kodak Res. Labs.

SPECIFIC GRAVITY, DENSITY & WEIGHT

Testing and Adjusting Scale Beams. C. A. Briggs. Scale Journal, Mar. 10, 1930, pages 9-10, 16.

A paper before the 15th Annual Convention of the National Scalemen's Association. Testing and adjustment of scale beams is discussed.

Some Questions Pertaining to the Design of Weighing Machines. W. M. Wilson. Scale Journal, March 10, 1930, pages 11-13.

The bearing capacity of knife-edges is discussed.

Theory on the Errors of Large Scales (Theorie der Fehler von Grosswaagen). Max Raudnitz. Messtechnik, Feb. 1930, pages 31-38.

A mathematical discussion.

Robust Microbalance of High Sensitivity for Weighing Sorbed Films. J. W. McBain & H. G. Tanner. Proceedings Royal Society, Nov. 1929, pages 579-586.

Details are given of a method of constructing a microbalance, an interesting feature of which is the use of carborundum crystals as balance points. These rest upon a fused silica flat. Erratic variations in the zero point of the balance were found to be due to electrostatic charges. The radiations from uranium oxide, placed near the balance, dissipated these effectively.—Abs. Bull. Kodak Research Labs.

X-RAY TESTING & EXAMINATION

Simple Method for the Determination of Orientation of a Crystal from a Laue Photograph. K. Yamaguski & S. Togins. Bulletin Institute of Physico-Chemical Research (Tokyo), Aug. 1929, 73 pages.

The authors claim that by using a new method involving a new crystallometric globe, the orientation of a crystal is more readily and accurately determined from its Laue photograph than be methods already in use. The apparatus is described in some detail.—Abs. Bull. Kodak Res. Lab.

X-Ray Motion Pictures. H. Umbehr. Filmtechnik, June 8, 1929, pages 249-252.

A historical sketch is given of attempts to produce x-ray motion pictures. The researches are divided into the direct method and indirect method. The direct method consists in making serial x-ray exposures in the standard size. The indirect method consists in photographing the fluorescent screen.—Abs. Bull. Kodak Research Labs.

The Multiple Crystal X-Ray Spectrograph. Jesse W. M. DuMond & Harry A. Kirkpatrick. Review of Scientific Instruments, Feb. 1930, pages 88-105.

The need for improvements in scattered X-ray spectroscopic technique along the lines of increased intensity and contrast is discussed and a new instrument composed of fifty small units, each a Seeman Spectrograph in itself cooperating to form a single spectrogram, is described in detail. The technique of adjusting the instrument is also described.

VISCOSITY

The Measurement of the Viscosity of Glass at High Temperatures by the Rotating Cylinder Viscometer. R. F. Proctor and R. W. Douglas. Proceedings. Physical Society, Aug. 15, 1929, page 500-519.

After reviewing previous work on the subject, the paper describes an apparatus in which the molten glass is contained in a cylindrical sillimanite pot provided with a coaxial cylindrical stirrer which is caused to rotate: the viscosity is inferred from the angular velocity produced in the stirrer by a measured torque. The apparatus was calibrated by measurement with it of the viscosities of golden syrup and pitch, these quantities being also measured independently with a falling sphere viscometer and by a torsion method respectively. The calibration factor of the authors' apparatus appears to be independent of the viscosity over a wide range. The authors' results and those of previous workers are considered to be in reasonable agreement with one another when allowance is made for differences in composition of the samples used.—M. B. R.

Two Hot-Wire Viscometers. E. G. Richardson. Journal Scientific Instruments, Nov. 1929, pages 337-343.

Instruments based on the convective cooling of an electrically heated wire, for giving the distribution of velocity across a liquid: 1. flowing in a cylindrical tube; 2. flowing in the annular space between 2 concentric cylinders, 1 rotating and the other at rest, are described. As examples of their use, the velocity gradients in a number of liquids at various stages between stream-line and turbulent flow are shown, and compared with the forces producing the flow. The use of a hot wire and a string galvanometer to detect unsteady flow is illustrated.—M. B. R.

Measurement of Absolute Viscosity by the Use of Concentric Cylinders. H. R. Lillie, Journal American Society, Aug. 1929, pages 505-519.

A method is described for the determination of absolute viscosities of liquids using the torque exerted on a stationary inner spindle suspended by means of a wire into the center of the fluid when the outer cylindrical container is rotated. A method of calibrating the suspensions is described. The true value of the viscosity is found by extrapolating values of apparent viscosity given spindles of various lengths but of equal radii to that value corresponding to infinite length. Castor oil was used as the test fluid. Using the "true" value of castor oil the author obtains the effective length and end effect of any spindle of definite dimensions.—Abs. Bull. Kodak Res. Labs.

Michell Viscometer. C. E. Fawkes. Paint, Oil and Chemical Review, July 25, 1929, pages 10-12.

The paper deals with the Michell viscometer which has found substantial use on the continent for oil testing. This viscometer is also suitable for measuring the viscosity of lacquers.—Abs. Bull. Kodak Res. Labs.

Selecting a Viscometer—An Interestng Problem. C. E. Fawkes. Paint, Oil and Chemical Review. Aug. 22, 1929, pages 12-15.

The author gives abstracts of the various references which were accumulated in attempting to find an accurate inexpensive, quick-acting viscometer for lacquer work.—Abs. Bull. Kodak Res. Labs.

PHOTOGRAPHY

Askania High Speed Camera. Kinotechnik, Mar. 5, 1929, pages 124-126; Lichtbildbuehne, Apr. 13, 1929, pages 18-19.

An ultra rapid camera known as the "trommel-apparat" employs a high frequency 30,000 volt arc for illumination. The arc current is supplied by a series of battery of nine Leyden jars and the light is intermittently flashed on the subject by means of a rotating sector. The film (perforated or unperforated) is wound on the inside of a specially constructed cylinder which accommodates 100 turns of 40 normal frames each. The film is held in absolute contact in the focal plane by centrifugal force. With this type of camera 4000 normal frames per second are possible. Exposure frequencies of 8000 and 16000 per second with frames of one-half and one-quarter normal heights are possible by increasing the intensity and frequency of the light pulses.—Abs. Bull. Kodak Res. Labs.

Cinematography on Stationary Film at Extremely High Picture Frequencies. C. Cranz & H. Schardin, Zeitschrift fuer Physik, July 1929, pages 147-182.

An apparatus is described by means of which it is possible to photograph a series of pictures of a rapid action on a stationary piece of film. The time between successive pictures can be varied from one-tenth to one-three-millionth of a second. There is no reason why the principle cannot be further extended. Several uses for the apparatus are discussed.—Abs. Bull. Kodak Res. Labs.

Modern Scientific Uses of Photography. H. J. Gramarski. Filmtechnik, May 25, 1929, pages 232-236.

A popular article setting forth some of the present day uses of photography in science. The following are among the uses mentioned: (1) The photography of electron and atom tracks (work of C. T. R. Wilson); (2) ultra-microscopic photography (Brownian movement); (3) X-ray cinematography (work of Gottheiner and Jacobsohn); (4) developments in stereo-cinematography; (5) studies of the motion of terrestrial bodies (recent film of Jupiter and its moons by Prof. Wright). Abs. Bull. Kodak Res. Labs.

Material Transference in the Welding Arc. A. Hilpert. Translated by H. Abrams. Journal American Welding Society, Vol., Dec. 1929, pages 20-23.

Moving picture exposures of the transfer of metal in the welding arc were taken, by special methods, at 1600 or more exposures per second. There are two types of drops formed, one thread-like which tapers off from the electrode end, the other mushroom-like which collects on the electrode before transference. The latter changes its shape greatly in 1/1600 sec. The work is being continued.

Application of Electric Arc-Welding. Alexander Churchward. Heat Treating & Forging, Oct. 1929, pages 1304-1306.

Includes description of special camera for studying formation of metallic globules at the tip of the electrode.—M. S.

BUYERS' GUIDE

Of instruments and devices for measurement, inspection or control.

If you are unable to find what you require in the Buying Section of INSTRUMENTS—write u and we will obtain full particulars for you without charge. Give complete information of requirements.

ABRASION TESTERS
H. Z. Schniewind

ACIDITY RECORDERS
Leeds & Northrup Co.
Rubicon Company

AIR FLOW INDICATOR
Brown Instrument Co.
Commercial Engg. Labs.
Foxboro Co.

AIR METERS
American Meter Co.

ALIDADES

ALTIMETERS
American Paulin System, Inc.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

AMMETERS—Indicating
General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

Recording
Bristol Company
Esterline-Angus Company

ANEMOMETERS
Taylor Instrument Companies

ARMATURE TESTING EQUIPMENTS
Westinghouse Elec. & Mfg. Co.

ASPHALT TESTING APPARATUS
Tagliabue Mfg. Co., C. J.

ATTENUATION NETWORKS
General Radio Company

AUDIO-FREQUENCY OSCILLATORS
General Radio Company

BALANCES
Akatos, Inc.
H. Z. Schniewind

BAROMETERS—Aneroid Mercurial, Recording
American Paulin System, Inc.
Bristol Company
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

BATHS—Constant temperature water & oil

BATTERY TESTERS
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

BOARDS: INSTRUMENTS
Foxboro Co.

BRAKE TESTING METER
Leeds & Northrup Co.

BRIDGES, ELECTRICAL

Capacities, Conductivity, Hoopes, Inductance, Kelvin, Resistance, Temperature, Wheatstone
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

CABLE TESTERS
Rawson Elec. Inst. Co.

CALORIMETERS—Gas
American Meter Co.
Burgess-Parr Co.

Peroxide, Oxygen Bomb
Burgess-Parr Co.
Gaertner Scientific Corp.

CAPACITANCE METERS
General Radio Co.
Rubicon Company

CARBON DIOXIDE METERS
American Meter Co.
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

CARBON MONOXIDE METERS
American Meter Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

CATHETOMETERS
Gaertner Scientific Corp.

CEMENT TESTING INSTRUMENTS

CHRONOGRAPHS
Gaertner Scientific Corp.

CHRONOMETERS
Tagliabue Mfg. Co., C. J.

CLOCKS—Gauge Board
Brown Instrument Co.
Bristol Company
Foxboro Co

CLOUD & POUR TEST APPARATUS
Tagliabue Mfg. Co., C. J.

COILS

Resistance, Inductance, Special.
General Radio Co.
Rubicon Company

COIL TESTING EQUIPMENTS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.

COLORIMETERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.

COMBUSTION CONTROL EQUIPMENT
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.

COMMUNICATION MEASURING INSTRUMENTS
General Radio Company

COMPASSES
Taylor Instrument Companies

COMPARATORS
B. C. Ames Co.
Federal Products Corp.
Gaertner Scientific Corp.

CONDENSER LEAKAGE RECORDERS
Esterline-Angus Company

CONDENSERS—Electrical
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

CONDUCTIVITY METERS

Indicating, Recording, Controlling
Esterline-Angus Company
Leeds & Northrup Co.

CONCENTRATION RECORDERS
Esterline-Angus Company
Leeds & Northrup Co.

CONSTANT SPEED & FREQUENCY SETS
Leeds & Northrup Co.

CONTOUR MEASURING PROJECTOR
Bausch & Lomb Optical Co.

CONTROLS, AUTOMATIC

Condensation
Tagliabue Mfg. Co., C. J.

Damper
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J

Feed Water
Brown Instrument Co.
Foxboro Co.

Filter Rate
Brown Instrument Co.
Foxboro Co.

Float

Flow
Brown Instrument Co.
Foxboro Co.

Gravity
Foxboro Co.
Tagliabue Mfg. Co., C. J.

Humidity
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Humidity & Temperature
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Liquid Level
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Tagliabue Mfg. Co., C. J

Motor

Pressure & Vacuum
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Esterline-Angus Company
Foxboro Co.
Tagliabue Mfg. Co., C. J
Taylor Instrument Companies

Pyrometer
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc

Rate-Volume
American Meter Co.
Foxboro Co.

Refrigeration
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

Special
Rubicon Company

Tachometer
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Leeds & Northrup Co.

VIBRATION, SOUND, LIGHT & COLOR

Measurement of the Color of Textile Fabrics and Some Applications to the Problems of Fading. P. W. Cunliffe. Journal Society Dyers & Colorists, Nov. 1929, pages 305-321.

Collection of five papers dealing with the application of the instruments mentioned, to the recording and interpretation of color, and of color change due to the facing of dyed textiles.—Abs. Bull. Kodak Res. Labs.

Ronchoni's Method of Optical Testing. J. A. Anderson & R. W. Porter. Astrophysical Journal, Oct. 1929, pages 175-181.

A modification of Ronchoni's slit and line screen method of testing a lens or mirror is described. A second line screen is substituted for the slit with resultant increase in illumination. With parallel light only one screen is necessary. Results show a sensitivity equal to that of the Foucault knife-edge test.—Abs. Bull. Kodak Res. Labs.

Quartz Spectrograph. Jobin & Yoon. Revue d'Optique, Aug. 1929, pages 311-313.

The authors describe a quartz spectrograph employing a concave mirror to collimate the light entering the slit and an objective lens to focus the spectrum on the plate. The arrangement of the parts is somewhat novel and produces an instrument that requires less room than the conventional arrangement of the same parts. The spectrum from 7,000 to 2,100 angstrom is reproduced on a photographic plate 24 cm. long.—Abs. Bull. Kodak Res. Labs.

New Photometer by Eastman. Bulletin of Photography, Dec. 4, 1929, pages 718-719.

Describes a device for measuring the printing quality of amateur negatives. The negative to be measured is placed over a small lighted "window" in the top of the desk and an arm containing a selenium cell is brought down on the negative. A reading of the energy reaching the cell is made, first through the lightest density and then the heaviest density. A dial is then rotated to correspond with a setting for each reading and punches are made along the side of the negative to indicate the grade of paper and time of exposure (for a known printer), to be used in printing the negative. —Abs. Bull. Kodak Res. Labs.

Determination of the Velocity of Light by Using the Kerr Electro-Optical Effect. A. Karolus & O. Mittelstaedt. Elektrotechnische Zeitschrift, Oct. 17, 1929, page 1529.

Light polarized 45 degrees to the electric field of a Kerr cell falls on a plane mirror, and is reflected back through a second Kerr cell whose electric field is 90 degrees to that of the first. By putting the same alternating electric field on both cells, and changing the frequency, an effect analogous to the Fizean rotating disk is observed. The path length was made large and the frequency high. The value of **c** is 299,778 km.-sec. M 20 km.-sec.—Abs. Bull. Kodak Res. Labs.

Application of Special Distribution Determinations to Maintenance of Color Standards. Paint, Oil and Chemical Review, Oct. 24, 1929, pages 91-93.

By means of spectral reflection, determinations made on a paint, its physical characteristics, far as color is concerned, may be completely specified.—Abs. Bull. Kodak Res. Labs.

Measurement and Recording of Instantaneous Light Variations by Means of the Photoelectric Cell and Stabilized Oscilloscope. W. E. Meserve. Transactions Illuminating Engineering Society, Sept. 1929, pages 671-683.

A detailed explanation with diagrams of apparatus and circuits is given. Illustrations of flicker curves obtained from several types of lamps operated on 30 cycle and 60 cycle current are included. —Abs. Bull. Kodak Res. Labs.

Light-Sensitive Cells. J. P. Arnold. Projection Engineering, Sept. 1929, pages 44-46.

The author divides light sensitive cells into three groups and describes them as photoconductive, photoelectric, and phot ovoltaic.—Abs. Bull. Kodak Res. Labs.

Acoustimeter. R. F. Norris. Projection Engineering, Sept. 1929, page 43.

A description of an electrical means for measuring sound intensities is given.—Abs. Bull. Kodak Res. Labs.

Whiteness of Paper. L. B. Desbleds. Paper Trade Journal., Nov. 14, 1929, pages 55-56.

The whiteness is measured by a newly devised photocolorimeter employing a photoelectric cell instead of the human eye. Barium sulfate is used as the standard of comparison. To determine the color of the paper, filters are employed between the light source and the specimen to be test. —Abs. Bull Kodak Res. Labs.

Burgess Exhaust and Intake Mufflers and Silencers. Engineering Circular No. 17, Burgess Battery Co., Dec. 7, 1929, 15 pages.

Exhaust and intake mufflers and silencers making use of sound absorption phenomena are described with an explanation of the methods of testing for loudness, back pressure, effect on engine power and endurance. The Acoustimeter, a new instrument for measuring sound is described. Several typical test curves are presented.

Measurements of Thermoluminescence of Glass Exposed to Light. R. E. Nyswander & B. E. Cohn. Journal Optical Society, Mar. 1930, pages 131-136.

Glass turned violet in color due to long exposure to sunlight is thermoluminescent when heated to temperatures above 100°C. Thermoluminescence was also observed in some samples free from color while others showed no luminescence. Effects similar to those for sunlight were also observed from glasses exposed to the carbon of mercury arc and in some cases for exposures of only a few minutes. Special glasses were made from a chemically pure zinc borate glass to which was added a trace of one of the following metals. barium, calcium, strontium, magnesium, manganese, aluminum, nickel, cobalt, chromium, silver, cerium, thallium, and thorium. Each of the above was exposed to sunlight and tested for thermoluminescence, the most intensely luminescent being thorium, cerium, silver, chromium, cobalt, and manganese. The following curves were determined: growth of luminescence with time of exposure, both for sunlight and the carbon arc; effect of concentration of solute; decay of thermoluminescence and periodic changes of luminescence as dependent upon time after excitation. All light measurements were made with a polarization photometer.

The Automatic Recording of the Infra-Red at High Resolution. F. S. Brackett & E. D. McAlister. Review Scientific Instruments, Mar. 1930, pages 181-193.

This article presents a description of the spectrometer, thermocouples and housing developed for making records of absorption and emission spectra. Typical records are included.

International Commission on Illumination. Plenary Session at Saranac Inn (September 1928). XXII. Work of the Committee on Photometric Standards. (Commission internationale de l'Eclairage. Session pleniere de Saranac Inn (Septembre 1928). XXII. (Travaux du Comite des Etalons photometriques). Review Generale de l'Electricite, Dec. 14, 1929, pages 947-958.

Summarizes earlier work presented at the various International Congresses and gives abstracts of papers presented at the seventh session, 1928.—M. S.

- **Temperature-Time**
  - Brown Instrument Co.
  - Charles Engelhard, Inc.
  - Foxboro Co.
  - Leeds & Northrup Co.
  - Tagliabue Mfg. Co., C. J.
  - Taylor Instrument Co.
- **Thermometer**
  - Bristol Company
  - Brown Instrument Co.
  - Charles Engelhard, Inc.
  - Foxboro Co.
  - Leeds & Northrup Co.
  - Tagliabue Mfg. Co., C. J.
  - Taylor Instrument Companies
  - Wilson-Maeulen Company, Inc.
- **Thermostat**
  - Bristol Company
  - Brown Instrument Co.
  - Charles Engelhard, Inc.
  - Foxboro Co.
  - Taylor Instrument Companies
  - Westinghouse Elec. & Mfg. Co.
- **Thickness**
  - Esterline-Angus Company
  - H. Z. Schniewind
- **Time**
  - Brown Instrument Co.
  - Esterline-Angus Company
  - Foxboro Co.
  - Stromberg Electric Co.
  - Tagliabue Mfg. Co., C. J
- **Vacuum**
  - Brown Instrument Co.
  - Esterline-Angus Company
  - Foxboro Co.
  - Meriam Co.
- **Unit Heater**
- **Valve—Motor Operated**
  - American Radiator Company
  - Bristol Company
  - Brown Instrument Co.
  - Charles Engelhard, Inc.
  - Foxboro Co.
  - Taylor Instrument Companies
- **Water Level**
  - Bristol Company
  - Brown Instrument Co.
  - Esterline-Angus Company
  - Foxboro Co.
  - Tagliabue Mfg. Co., C. J.

- **COORINATOGRAPHS**
- **COUNTERS**—Revolution
  - Bristol Company
  - Brown Instrument Co.
  - H. Z. Schniewind
- **Stroke**
  - Bristol Company
  - Esterline-Angus Company
- **COUPLING TRANSFORMERS**
  - General Radio Company
- **CURRENT RECORDERS**
  - Esterline-Angus Company
  - Leeds & Northrup Co.
- **CURRENT REGULATORS**
  - Westinghouse Elec. & Mfg. Co.
- **CYCLE COUNTERS**
  - General Radio Co.
- **CYLINDERS-GRADUATED**
  - Tagliabue Mfg. Co., C. J.
- **DECELEROMETER**
- **DEFORMETER (Beggs)**
  - Southwark Fdy. & Mach. Co.
- **DEMAND METERS**
  - **Gas**
    - American Meter Co.
  - **Electric**
    - Westinghouse Elec. & Mfg. Co.
- **DENSITOMETERS**
  - Akatos, Inc.
- **DENSOMETERS**
  - H. Z. Schniewind
- **DIVIDING HEAD**
  - **Optical**
    - Bausch & Lomb Optical Co.
    - Industrial App. & Inst. Co.
- **DIVIDING MACHINES**
  - Gaertner Scientific Corp.
- **DRAFT GAGES**—see Gages
- **DYNAMIC BALANCING EQUIPMENT**
  - Electrocon Corporation
- **EARTH CURRENT METERS**
  - Rawson Elec. Inst. Co.
- **ELECTRIC TELEMETER**
  - Southwark Fdry. & Mach. Co.
- **ELECTRIC WAVE FILTER SECTIONS**
  - General Radio Company
- **EMPLOYEES' "IN AND OUT" TIME RECORDERS**
  - Stromberg Electric Co.
- **ENGINE INDICATORS**
  - Commercial Engg. Labs.
- **EXTENSOMETER**
  - H. Z. Schniewind
  - Southwark Fdry. Mach. Co.
- **FATIGUE TESTERS**
  - H. Z. Schniewind
- **FAULT FINDERS**
  - General Radio Co.
  - Leeds & Northrup Co.
  - Rubicon Company
  - Weston Electrical Inst. Corp.
- **FLASH & BURNING POINT TESTERS**
  - Akatos, Inc.
  - Tagliabue Mfg. Co., C. J.
  - Taylor Instrument Co.
- **FLOW METERS**
  - American Meter Co.
  - Brown Instrument Co.
  - Foxboro Co.
  - Meriam Co.
- **FLUXMETERS**
  - Leeds & Northrup Co.
  - Rawson Electrical Instr. Co.
- **FOLDING TESTER**
  - H. Z. Schniewind
- **FREQUENCY METERS**
  - **Indicating**
    - Jewell Electrical Instrument Co.
    - Leeds & Northrup Co.
    - Westinghouse Elec. & Mfg. Co.
    - Weston Elec. Inst. Corp.
  - **Controlling**
    - Leeds & Northrup Co.
  - **Recording**
    - Bristol Company
    - Esterline-Angus Company
    - Leeds & Northrup Co.
  - **Standards**
    - General Radio Co.
- **FUEL ANALYSIS APPARATUS**
  - Burgess-Parr Co.
- **FUEL FLOW INDICATOR**
  - Commercial Engg. Labs.
- **GALVANOMETERS**
  - Brown Instrument Co.
  - Charles Engelhard, Inc.
  - General Radio Co.
  - Jewell Electrical Instrument Co.
  - Leeds & Northrup Co.
  - Rubicon Company
  - Westinghouse Elec. & Mfg. Co.
  - Weston Electrical Inst. Corp.
- **GAS ANALYTICAL METERS**
  - **Chemical**
    - American Meter Co.
    - Tagliabue Mfg. Co., C. J.
  - **Electrical**
    - Brown Instrument Co.
    - Charles Engelhard, Inc.
    - Leeds & Northrup Co.
- **GAS LEAK INDICATORS**
  - Taylor Instrument Companies
- **GAS-METERS**
  - American Meter Co.
  - Brown Instrument Co.
  - Foxboro Co.
  - Meriam Co.
- **GASOMETERS**
  - American Meter Co
- **GAGE RODS**
  - Tagliabue Mfg. Co., C. J.
- **GAGES**
  - **Absolute Pressure**
    - Brown Instrument Co.
    - Foxboro Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Companies
  - **Amplifying**
    - B. C. Ames Co.
    - Federal Products Corp.
  - **Comparator**
    - B. C. Ames Co.
    - Federal Products Corp.
  - **Cylinder**
    - B. C. Ames Co.
    - Federal Products Corp.
  - **Depth**
    - B. C. Ames Co.
    - Federal Products Corp.
  - **Dial**
    - B. C. Ames Co.
    - Federal Products Corp.
    - H. Z. Schniewind
  - **Differential Pressure**
    - American Meter Co.
    - Brown Instrument Co.
    - Foxboro Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J
  - **Draft**
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Companies
  - **Drill**
    - Bausch & Lomb Optical Co.
    - Industrial App. & Inst. Co.
  - **Grinding**
    - Federal Products Corp.
  - **Liquid Level**
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Leeds & Northrup Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Companies
  - **Loss of Head**
    - Brown Instrument Co.
    - Foxboro Co.
    - Meriam Co.
  - **Pitch Diameter**
    - Federal Products Corp.
  - **Pocket**
    - H. Z. Schniewind
  - **Pressure**
    - American Meter Co.
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Leeds & Northrup Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Companies
  - **Pressure-Temperature**
    - Bristol Company
    - Brown Instrument Co.
    - Foxboro Co.
    - Leeds & Northrup Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Cos.
  - **Pressure & Vacuum**
    - Bristol Company
    - Brown Instrument Co.
    - Charles Engelhard, Inc.
    - Foxboro Co.
    - Leeds & Northrup Co.
    - Meriam Co.
    - Tagliabue Mfg. Co., C. J.
    - Taylor Instrument Companies
  - **Profile**
    - Bausch & Lomb Optical Co.
    - Industrial App. & Inst. Co.
  - **Rain**
    - Taylor Instrument Companies

Measurement of the Contrast Ratio of Opaque and Translucent Papers. J. Clark. Paper Trade Journal, Nov. 14, 1929, pages 62-64.

This instrument was devised by the U. S. Bureau of Standards, and consists of a wooden box lined with opal glass and uniformly illuminated from within by diffused artificial light. At one end of the box are two areas, one a perfectly black surface consisting, of a small cavity lined with black velvet which effectively absorbs all the light that enters, and the other a perfectly white surface, consisting of a disk thickly coated with magnesium oxide, prepared by exposing the surface to the smoke of a burning magnesium ribbon, or a disk of pure magnesium carbonate. A sample of the material to be tested is inserted in a holder directly in front of, and as close as possible to, the standard areas, which are then viewed through a form of Wanner or Martens photometer mounted on the other end of the chamber. The field seen by the observer is divided into two semi-circles illuminated respectively by (a) light reflected from the paper only (the transmitted light being absorbed by the black cavity), and (b) light reflected from the paper plus that reflected through the paper from the white surface beneath. The eyepiece to which is attached a scale pointer and analyzing nicol prism, is rotated until two semi-circles appear equally illuminated when a reading is taken on the scale. A check reading is also taken with the photometer turned through 180 degrees.—Abs. Bull. Kodak Res. Labs.

HEAT UNITS & COMBUSTION

Automatic Boiler Control Installation at the Chantenay Power-Plant (Installation de réglage automatique de chaudieres a l'usine generatrice thermique de Chantenay). J. Hak, Revue Generale de l'Elecrticite, Dec. 14, 1929, pages 969-974.

Describes installation which is claimed to be first made in France. The Roucka system of indicating and recording instruments and control apparatus is used. Gives some observations on the action of the apparatus and the results of some comparative evaporative tests. The combustion regulator is based on a very simple equation, which is presented.—M. S.

The Electric Boiler Control (Die elektrische Kesselregelung). W. Jaekel. Elektrizitaet im Bergbau, Nov. 18, 1929, pages 208-212.

The Siemens & Halske boiler control is described.

Considerations on the Present Status of Quantity Measurements and Allied Fields (Betrachtungen ueber den gegenwaertigen Stand der Mengenmesstechnik und verwandter Gebiete) F. Schomber. Messtechnik, Dec. 1929, pages 335-336.

Regulator for automatic boiler control is described.

Calorimetric Determinations of Heats of Adsorption. A. Magnus & G. Giebenhain. Zeitschrift fuer Physikalische Chemie, Sec. A, No. ¾, 1929, pages 265-277.

A calorimeter is described for accurately measuring the heat of adsorption of carbon dioxide on silica gel and charcoal at low pressures. At low pressures, where Henry's law is observed, the heat of adsorption is independent of the pressure, but at higher pressures the heat of adsorption gradually decreases. At low pressures the heat of adsorption of carbon dioxide on silica gel is about 7400 calories per mol at 0°C. and about 7000 calories per mol at 25°C.—Abs. Bull. Kodak Res. Labs.

SPECIAL

Cobalt-Steel Magnets in Aircraft Compasses. John L. Gier. Electric Journal, Feb. 1930, pages 114-115.

If the "figure of merit" of a magnet steel is the maximum value of the product of its retained induction, Bd, in gausses by the corresponding demagnetizing force, Hd, in gilberts per cm. the curves show that for cobalt steel the BdHd max. M102 x 10-4, as compared to BdHd max. M32 x 10-4 for chromium steel. U. S. Air Corps compasses built by the Aircraft Control Corp. of Philadelphia contain this cobalt steel. Their construction is indicated diagrammatically. The use of this steel has permitted a reduction in size and weight of compasses, and a gain in stability and performance.—W. H. B.

New!

Don't buy that high-range insulation testing outfit until you get details on the New Paragon constant-pressure Megohmer. Available in ranges from 0-1,000 megohms to 6-10,000 megohms with generators rated 400 to 2,500 volts D. C.

Herman H. Sticht & Co.
21 PARK ROW, NEW YORK, N. Y.

When writing to the above company, please mention INSTRUMENTS

Recording
Distance
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Strain
Southwark Fdry. & Mach. Co.
Thickness
B. C. Ames Co.
Esterline-Angus Company
H. Z. Schniewind
Volume
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Water Level for Boilers
Bristol Company
Brown Instrument Co.
Foxboro Co.
Wind
Brown Instrument Co.
Taylor Instrument Companies
GEOPHYSICAL INSTRUMENTS
Akatos, Inc.
GOVERNORS
Laboratory Dry & Wet Gas
American Meter Co.
Pressure
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Pump
Tagliabue Mfg. Co., C. J.
GLASS STRAIN TESTERS
Akatos, Inc.
GREASE TESTING APPA.RATUS
Tagliabue Mfg. Co., C. J
GROUND DETECTORS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electric Inst. Corp.
GROUND-OHMER
Leeds & Northrup Co.
Herman H. Sticht & Company
GYPSUM TESTING INSTRUMENTS
H. Z. Schniewind
HARDNESS TESTERS
Akatos, Inc.
Industrial App. & Inst. Co.
H. Z. Schniewind
Wilson-Maeulen Company, Inc.
HARMONIC ANALYZERS
Leeds & Northrup Co.
HELIOSTATS
Gaertner Scientific Corp.
HIGH FREQUENCY APPARATUS
Argco Laboratories, Inc.
HIGH VOLTAGE
Indicators
Argco Laboratories, Inc.
Measuring Devices
Westinghouse Elec. & Mfg. Co.
Testing Devices
Westinghouse Elec. & Mfg. Co.
HUMIDITY CONTROLLERS
Bristol Company
Charles Engelhard, Inc.
Foxboro Co.
HUMIDITY RECORDERS
Wet & Dry Bulb Thermometers
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
HYDROGEN ION METERS
Indicating
Leeds & Northrup Co.
Rubicon Company
Controlling, Recording
Leeds & Northrup Co.

HYDROMETERS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
HYGROMETERS
Brown Instrument Co.
Foxboro Co.
H. Z. Schniewind
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
IMPACT HARDNESS TESTER
H. Z. Schniewind
IMPACT TESTING MACHINES
Akatos, Inc.
H. Z. Schniewind
Alternating
INDICATORS—See Gauges
INDUCTANCES
General Radio Co.
Rubicon Company
INSTRUMENT BOOKS
Instruments Publishing Co.
INSTRUMENT CALIBRATION AND REPAIRS
Jewell Electrical Instrument Co.
Rubicon Company
INSTRUMENT TRANSFORMERS
Jewll Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
INSULATION TESTING EQUIPMENT
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
INTEGRAPHS & INTEGRATORS
Leeds & Northrup Co.
INTERFEROMETERS
Gaertner Scientific Corp.
JOB TIMING RECORDERS
Stromberg Electric Co.
KEYS AND SWITCHES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company
KILNBOY
Foxboro Co.
KILOVOLT AMPRERE METERS
Esterline-Angus Company
KLYDONOGRAPHS
Westinghouse Elec. & Mfg. Co.
LACTOMETERS
Tagliabue Mfg. Co., C. J.
LENGTH MEASURING MACHINES
Gaertner Scientific Corp.
H. Z. Schniewind
LEVELS
Centering
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Enginerr's, Wye, Precision
Prism
Taylor Instrument Companies
LIME TESTING INSTRUMENTS
American Instrument Company
LOCOMOTIVE INDICATORS
LUSTER METERS
Akatos, Inc.
MAGNETOMETERS
Rubicon Company
MANOMETERS
American Paulin System, Inc.
Brown Instrument Co.
Foxboro Co.
Meriam Co.
MASTER CLOCKS
Gaertner Scientfiic Corp.
Stromberg Electric Co.
MEASUREMENT BOOKS
Instrument Publishing Co.
MEGOHMMETERS
Leeds & Northrup Co.
Rubicon Company
Herman H. Sticht and Company
MEGOHM VOLTMETERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

MELTING POINT APPARATUS
Tagliabue Mfg. Co., C. J.
METER PROVERS, Gas
American Meter Co.
METER TESTERS, Gas
American Meter Co.
MICROMETERS
Gaertner Scientific Corp.
H. Z. Schniewind
MICROAMMETERS
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.
MICROFARADMETERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.
MICRO PYROMETERS
Akatos, Inc.
MICROSCOPES
Brinell
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.
H. Z. Schniewind
Spencer Lens Co.
Metallographic
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Spencer Lens Co.
Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Spencer Lens Co.
Toolmakers'
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.
Spencer Lens Co.
MICROTOMES
Bausch & Lomb Optical Co.
Spencer Lens Co.
MILLIAMMETERS
Charles Engelhard, Inc.
General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.
MILLIVOLTMETERS
Bristol Company
Charles Engelhard, Inc.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co
Taylor Instrument Companies
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.
MOTION RECORDERS
Mechanical
Bristol Company
MULTIMETERS
Rawson Electrical Instrument Co.
MULTIPLIERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Electrical Inst. Corp.
NEON FILLED TUBES
Argco Laboratories, Inc.
NEPHELOMETERS
Akatos, Inc.
OHM METERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.
OIL-TESTING APPARATUS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
OIL TESTING EQUIPMENT

OPERATION RECORDERS
Electrical
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
ORIFICE METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.
ORSAT APPARATUS
OSCILLOGRAPHS
General Radio Co.
Westinghouse Elec. & Mfg. Co.
OXYGEN RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
PANTOGRAPHS
Gaertner Scientific Corp.
PERFORMANCE METER
PERMEAMETERS
Leeds & Northrup Co.
Rubicon Company
PAPER TESTING INSTRUMENTS
H. Z. Schniewind
Spencer Lens Co.
PERISCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
PHASE INDICATOR
Westinghouse Elec. & Mfg. Co.
PHASE SEQUENCE INDICATO
Herman H. Sticht Co.
PHOTO-ELECTRIC CELLS
Argco Laboratories, Inc.
PHOTOMETERS
Akatos, Inc.
American Meter Co.
Gaertner Scientific Corp.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Leeds & Northrup Co.
PHYSICAL TESTING MACHINES
Industrial App. & Inst. Co.
H. Z. Schniewind
Southwark Fdry. & Mach. Co.
PITOT TUBE METER
Brown Instrument Co.
Foxboro Co.
PLANIMETERS
Automatic Flow Record
Brown Instrument Co.
Linear
Brown Instrument Co.
Radial
American Meter Co.
Bristol Company
Bristal Company
Foxboro Co.
Square Root
Foxboro Co.
POLARISCOPES
Akatos, Inc.
Gaertner Scientific Corp.
POSITION RECORDERS
Bristol Company
Esterline-Angus Company
Foxboro Co.

POTENTIAL DETECTORS
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

POTENTIOMETERS—Indicating
Brown Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Recording & Controlling
Foxboro Co.
Leeds & Northrup Co.

POWER FACTOR METERS
Esterline-Angus Company
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Eelectrical Inst. Corp.

POWER FACTOR REGULATORS
Rubicon Company
Westinghouse Elec. & Mfg. Co.
PRESSURE RECORDERS
Esterline-Angus Company
PRICESS TIMING AND SIGNALING INSTRUMENTS
Stromberg Electric Co.
PROGRAM INSTRUMENTS
Stromberg Electric Co.
PROJECTION LANTERNS
Bausch & Lomb Optical Co.
Spencer Lens Co.
PROTRACTOR
Optical
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
PSYCHROMETER
Recording
Bristol Company
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Sling
Taylor Instrument Companies
PYROMETERS
Optical
Leeds & Northrup Co.
Pyrometer Instrument Company
Radiation
Indicating
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Recording
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Thermo-electric
Immersion
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Indicating
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Wilson-Maeulen Company, Inc.
Recording and Controlling
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Surface Contact
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
RADIO FREQUENCY OSCILLATORS
General Radio Company
RADIO SET ANALYZERS
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.
RADIO TUBE CHECKERS
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.
RADIO TEST PANEL
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.
REFRACTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.

REGULATORS—See Controls
RELAYS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
REMOTE METERING EQUIPMENT
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
RESISTANCES—Electrical
General Radio Co.
Leeds & Northrup Co.
Spencer Lens Co.
RHEOSTATS
General Radio Co.
Rubicon Company
Spencer Lens Co.
ROTOSCOPE
Commercial Engg. Labs.
RUBBER TESTING INSTRUMENTS
H. Z. Schniewind

SACCHARIMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Spencer Lens Co.
Taylor Instrument Companies

SACCHROMETERS
Tagliabue Mfg. Co., C. J.
SALINITY INDICATORS
Rubicon Company
SCALES
Amthor Testing Instrument Co.
Gaertner Scientific Corp.
H. Z. Schniewind

SCRATCH HARDNESS TESTER
SEISMOGRAPHS
Akatos, Inc.

SERVICE RECORDERS
Esterline-Angus Company

SHUNT METERS
SHUNTS
Esterline-Angus Company
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.
SIGNALLING DEVICES—Automatic
Brown Instrument Co.
Stromberg Electric Co.
SLIDE RULES
SOIL PRESSURE CELLS
SPECIAL INSTRUMENTS
Burgess-Parr Co.
Meriam Co.
H. Z. Schniewind

SPECIAL ELECTRICAL INSTRUMENTS
Brown Instrument Co.
Charles Engelhard, Inc.
Esterline-Angus Company
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Weston Electrical Inst. Corp.

SPECIAL RECORDING DEVICES
Esterline-Angus Company
SPECIFIC GRAVITY APPARATUS
Gas,
American Meter Co.
SPECTROGRAPHS
Gaertner Scientific Corp.

SPECTROSCOPES
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.
Spencer Lens Co.

SPECTROPHOTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.

SPEED INDICATORS
See Tachometers
SPEED RECORDERS
Esterline-Angus Company
STANDARD CELLS
Weston Electrical Inst. Corp.
STEEL TAPES

STOP WATCHES
American Meter Co
STRAIN GAUGE
Southwark Fdry. & Mach. Co.

STRESS INDICATOR
STROBOSCOPES
Argco Laboratories, Inc.
Commercial Engg. Labs.

SULPHUR DIOXIDE METERS
American Meter Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

SULPHUR DETERMINATION APPARATUS
Burgess-Parr Co.
Tagliabue Mfg. Co., C. J.

SUNSHINE RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies

SUPERPRESSURE CATALYST EQUIPMENT
SURGE RECORDERS
Esterline-Angus Company

SYNCHRONIZING FORKS—Electrical
General Radio Co.
Leeds & Northrup Co.
TACHOSCOPES
Brown Instrument Co.

TACHOMETERS
Amthor Testing Instrument Co.
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
H. Z. Schniewind
Herman H. Sticht & Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

TELESCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.
TENSILE TESTERS FOR PAPER, WIRE, SHEETS, ETC.
Amthor Testing Instrument Co.
H. Z. Schniewind

TENSIOMETERS
American Paulin System, Inc.
TENSOMETER (Huggenberger)
Southwark Fdry. & Mach. Co.
TESTERS, Gas
American Meter Co.

TESTING MACHINE—Universal
H. Z. Schniewind
Southwark Fdry. & Mach. Co.

TEXTILE TESTING INSTRUMENTS
H. Z. Schniewind
THEODOLITES

THERMO-JUNCTIONS (Electric)
General Radio Co.
Rawson Electrical Instrument Co.

THERMOMETERS
Gas Filled
Bristol Company
Brown Instrument Co.
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

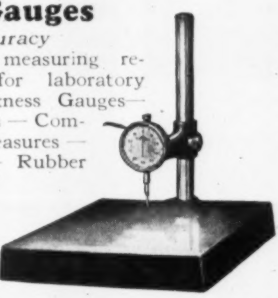
Mechanical
American Meter Co.
Brown Instrument Co
Foxboro Co.
Tagliabue Mfg. Co. C. J
Mercurial
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Resistance
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Wilson-Maeulen Co., Inc.
Vapor-Tension
Bristol Company
Brown Instrument Co.
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
THERMOSTATS
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Taylor Instrument Companies
Tagliabue Mfg. Co., C. J.
TIME OPERATION RECORDERS
Bristol Company
Esterline-Angus Company
Foxboro Co.
Tagliabue Mfg. Co., C. J.
TIME RECORDERS
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Gaertner Scientific Corp.
Foxboro Co.
TIME SWITCHES
Westinghouse Elec. & Mfg. Co.
TIME STAMPS—Automatic
Stromberg Electric Co.
TIME SYSTEMS—Electric
Stromberg Electric Co.
TIMERS
Leeds & Northrup Co.
Rawson Elec. Inst. Co.
Stromberg Electric Co.
TINTOMETER
TORSIOGRAPH
TRANSFORMERS
Esterline-Angus Company
General Radio Co.
TRANSITS
Engineer's, Surveyors, Mine,
Gaertner Scientific Corp.
Pocket
Taylor Instrument Companies
TUNING FORKS—Electrically Driven
General Radio Co.
Gaertner Scientific Corp.
Rubicon Company
"U" GAGES
Amthor Testing Instrument Co.
VACUUM RECORDERS
Bristol Company
Esterline-Angus Company
VACUUM TUBE BRIDGES
General Radio Company

VALVES
Automatic Shut Off
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Balanced
Brown Instrument Co.
Foxboro Co.

Diaphragm
Bristol Company
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Electrically Operated
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Reducing
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Regulating
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Safety, Fuel Shut-off
Tagliabue Mfg. Co., C. J.
VENTURI METERS
Brown Instrument Co.
Foxboro Co.
VIBROGRAPH
VIBROMETER—DAVEY
Electrocon Corporation
VIBROSCOPE
Electrocon Corporation

VISCOSIMETERS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
VISCOSITY TUBES
VOLTAGE DIVIDERS
General Radio Co.
VOLT-AMMETERS
Esterline-Angus Company
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
VOLTMETERS
Indicating
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
Recording
Bristol Company
Esterline-Angus Company
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Thermionic, Oxide Rectifers
General Radio Co.
WATER METERS
Foxboro Co.
WATER & SEDIMENT APPARATUS
Tagliabue Mfg. Co., C. J.
WATTHOUR METERS
Westinghouse Elec. & Mfg. Co.
WATTMETERS
Indicating
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
Recording
Bristol Company
Esterline-Angus Company
WAVEMETERS
General Radio Co.
WAX MELTING APPARATUS
Tagliabue Mfg. Co., C. J.



Ames Micrometer Gauges

for speed and extreme accuracy

For almost every testing and measuring requirement—Precision Instruments for laboratory use — Upright Dial Gauges—Thickness Gauges—Dial Gauge Heads — Pocket Gauges — Comparators — Densimeters — Lens Measures — Halftonometers — Paper Gauges — Rubber Gauges—Automotive Gauges.

Send for complete information about them

B. C. AMES CO., Waltham, Mass.

Detroit Office, 902 Stephenson Bldg.

ADVERTISERS' INDEX

A

Akatos, Inc., 14-118 Liberty St., New York, N. Y. 15
American Paulin System, Inc., 1220 Maple Ave., Los Angeles, Calif. 5
Ames, Co., B. C. Waltham, Mass. 25
Argco Laboratories, Inc., 150 W. Twenty-Second St., New York, N. Y. 15
Automatic Temperature Control Co., 34E Logan St., Philadelphia, Pa. 25

B

Bausch & Lomb Optical Co., 637 St. Paul St., Rochester, N. Y. 1
Bristol Company, Waterbury, Conn. .... Back Cover
Brown Instrument Company; 4482 Wayne Ave., Philadelphia, Pa. 3

C

Chicago Moulded Products Co., 2146 Walnut St., Chicago, Ill. 15
Commercial Engineering Labs., 4612 Woodward Ave., Detroit, Mich. 26

E

Esterline-Angus Company, Indianapolis, Ind. 6

F

Federal Products Corp., Providence, R. I. 26
Fleischhauer & Son; Fr., 8936-187 Place, Hollis, L. I., New York 25
Foxboro Co., Inc., Foxboro, Mass. 7

G

Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, Ill. 340
General Radio Company, Cambridge, A., Massachusetts 15

L

Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. 8

M

Meriam Company, Madison Ave., at W. 112 St., Cleveland, Ohio 12

R

Rawson Electrical Instrument Co., 90-92 Windsor St., Cambridge, Mass. 4
Rubicon Company, 29 North Sixth St., Philadelphia, Pa 12

S

Schniewind, H. Z., 72 Duane St., New York, N. Y. 13
Southwark Foundry & Machine Co., 400 Washington Ave., Philadelphia, Pa. 13
Sticht & Co., Herman H., 21 Park Row, New York, N. Y. 21

T

Tagliabue Mfg. Co., C. J., 18 to 99 Thirty-third St., Brooklyn, N. Y. Inside Front Cover
Taylor Instrument Co., 95 Ames St., Rochester, N. Y. .... Inside Back Cover

W

Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J. 2
Wilson-Maeulen Co., 387 Concord Ave., New York, N. Y. 10

Thermometers and Hydrometers

Industrial—Scientific

Prices on Request

FR. FLEISCHHAUER & SON

8936—187 Place Hollis, N. Y.

Control of Temperature Pressure, Level, Flow, Etc.

SEE OUR CATALOGUE IN SWEETS

Automatic Temperature Control Co., Inc.

Philadelphia Penna

INDEX CARD SECTION

A file card index will be a valuable asset. It is suggested that this index information be cut out mounted on cards, and filed in your desk or in a file box on top of your desk. You will then have within easy reach an index of instrument information of incalculable value.

THE PRACTICAL DIFFICULTIES OF INTRODUCING THE METRIC SYSTEM INTO THE UNITED STATES.

WILLIAM E. BULLOCK, INSTRUMENTS, Vol. 3, No. 5, May 1930, pages 279-282.

A brief discussion.

MEASUREMENT OF AIR FLOW.

E. OWER, INSTRUMENTS, Vol. 3, No. 5, May 1930, pages 283-293, 3 figs.

Chapter V. This is the fifth installment of a series, and covers measurements of flow and resistance with pilot-static tubes.

MEASUREMENTS—INDUSTRIAL & SCIENTIFIC.

DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, No. 5, May 1930, pages 295-316, 12 figs.

Chapter XIII. This chapter covers the measurement of temperature.

THE ENGINEER'S HANDBOOK OF INDUSTRIAL INSTRUMENTS.

M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 5, May 1930, pages 317-336, 16 figs.

Chapter II, Part 4—Radiation and Optical Pyrometers. This is the fifth installment of a series of articles on industrial instruments. Radiation and optical pyrometers are considered in detail.

FEDERAL
DIAL INDICATORS

Comparators
Amplifying Gauges
Thickness Gauges
Depth Gauges
Thread Lead Gauges
Pitch Diameter Gauges
Cylinder Gauges
Paper Gauges
Fabric Gauges
Rubber Gauges
Tap Comparator Gauges
Gear Toote Comparators
Cutter Testing Gauges
Internal and External
Grinding Gauges

Federal Products Corporation
Providence, R. I.
WESTERN BRANCH; 7338 WOODWARD AVE., DETROIT, MICH.

PRECISION INSTRUMENTS *for* AUTOMOTIVE LABORATORIES

AIR FLOW INDICATORS
FUEL FLOW INDICATORS
SLOW MOTION STUDY EQUIPMENT
MULTI CYLINDER ENGINE INDICATORS

COMMERCIAL ENGINEERING LABORATORIES
Makers of Fine Instruments

4612 WOODWARD AVENUE DETROIT, MICHIGAN

When writin to the above companies, please mention INSTRUMENTS

For High Temperatures—the *Tycos* Féry Radiation Pyrometer

Showing the *Tycos* Féry Radiation Pyrometer on one of the many applications. Can be set up in one minute or used without tripod. Below, the instrument and indicator.

THE ideal instrument for measuring high temperatures anywhere from 1000 F to 3600° and higher is the *Tycos* Féry Radiation Pyrometer. It is used on hundreds of important applications, including iron and steel manufacture, copper and zinc smelting, glass, ceramic and brick manufacrure, and gas plants.

The *Tycos* Radiation Pyrometer is optical only in the method of focusing. When once focused the temperature indication is read directly on the scale of the meter. There are no slide wires to adjust, no batteries or lamps to renew. As it is used away from the heat the instrument will last indefinitely.

The *Tycos* Radiation Pyrometer is amazingly accurate, giving true values within 1% at the middle of the scale and above. It operates by focusing the heat rays on a small thermo-couple, the e.m.f. being converted to degrees of temperature on the high resistance portable indicator. Comes complete with carrying case, 15 feet of cable, and instruction book with correction tables for special applications.

WRITE for *Tycos* Catalog 4000 showing the full line of *Tycos* Indicating, Recording and Controlling Pyrometers, in portable, wall type, and radiation models.

Taylor Instrument Companies

ROCHESTER, N. Y., U. S. A.

CANADIAN PLANT
TYCOS BUILDING
TORONTO

MANUFACTURING DISTRIBUTORS
IN GREAT BRITAIN
SHORT & MASON, LTD., LONDON

THE SIXTH SENSE OF INDUSTRY

Tycos Temperature Instruments

INDICATING - RECORDING - CONTROLLING